



Missouri Department of Natural Resources

Biological Assessment and Metals Characterization Report

Fredericktown Area:

**Logtown Branch (WBID 3203), Little St. Francis River (WBID 2854),
and Shays Creek (WBID 2865)
Madison County**

Fall 2015 – Spring 2016

Prepared for:

Missouri Department of Natural Resources
Division of Environmental Quality
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Water Pollution Control Branch

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1.0 Introduction

The Fredericktown area streams included in this study are Logtown Branch, Little St. Francis River (**LSFR**), and Shays Creek. All are located in the Ozark/Upper St. Francis/Castor River Ecological Drainage Unit (Figure 1) in Madison County, Missouri (Figure 2).

Logtown Branch (WBID U2854) is an unclassified stream that flows northeast from near Highway 67 for approximately 1.0 mile before reaching its confluence with Little St. Francis River, approximately 2.0 miles northeast of Fredericktown (Figure 2; Table 1). Logtown Branch has a drainage area of 0.8 square miles. Due to its small size, Logtown Branch has no identified beneficial use designations.

Little St. Francis River (WBID 2854) is a class P stream that flows for approximately 32.0 miles through southeast St. Francois County into northcentral Madison County (Figure 2; Table 1). Its drainage area covers approximately 51.0 square miles. The stream reaches its confluence with St. Francis River approximately 7.5 miles west of Fredericktown. Little St. Francis River has beneficial use designations that include livestock and wildlife watering (**LWW**), protection of aquatic life (**AQL**), whole-body contact – category A; cool-water fishery (**CLF**), secondary contact recreation (**SCR**), and drinking water supply (**DWS**). Whole body contact category A is defined as

...waters that have been established by the property owner as public swimming areas welcoming access by the public for swimming purposes and waters with documented existing whole body contact recreational use(s) by the public. Examples of this category include, but are not limited to: public swimming beaches and property where whole-body contact recreational activity is open to and accessible by the public through law or written permission of the landowner (MoDNR 2014).

Shays Creek (WBID 2865) is a class C stream approximately 0.25 miles northeast of Junction City and Fredericktown, Missouri (Figure 2; Table 1). The stream flows for approximately 1.1 miles from near County Road 217 past Old Jack Mine to a mine tailings basin known as the “Slime Pond.” From the Slime Pond it flows another 1.7 miles to the confluence with Village Creek (WBIDs 2863 and 2864) near northcentral Junction City, north of Fredericktown. Its total length, including the Slime Pond, is approximately 3.0 miles. Shays Creek has a drainage area of 3.1 square miles. Its beneficial uses include livestock and wildlife watering (**LWW**), protection of aquatic life (**AQL**), and whole-body contact (**WBC**), category B (MDNR 2014). The WBC “category B” applies to waters designated for whole body contact recreation not contained within category A.

1.1 Justification

The Fredericktown area streams included in this project are within or associated with an area known as the Madison County Mines Superfund Site (United States Environmental Protection Agency [EPA] Facility ID: MOD098633415). Located in what is known as the Old Lead Belt, this area is approximately 80 miles south of St. Louis, Missouri (ATSDR 2005; EPA 2017b). The majority of the abandoned mine workings are located within 6 miles of each other and cover approximately 645 acres around the city of Fredericktown (ATSDR 2005).

Metals were discovered in the area in the early 1700s and have been a primary source of lead from the American Revolution to the Korean Conflict (MoDNR 2010b). Mining continued to the mid-1900s (ATSDR 2005; EPA 2017b; MoDNR 2010b). At times, these metals included predominantly lead, but copper, cobalt, nickel, iron, zinc, and silver were also mined at some locations. Past mining operations at the Madison County Mines site have left at least 13 major tailings and chat deposits from mineral processing and smelting operations within the county.

The EPA identified “contaminants of concern” (**COC**) for the Madison County Mine Site. The COCs are the chemical substances found at the site that the EPA has determined pose an unacceptable risk to human health or the environment (EPA 2017a). The EPA listed arsenic, cadmium, cobalt, copper, lead, manganese, and nickel as COCs that have been found in groundwater, sediment, soil, solid waste, and surface water. The site status indicates that construction is not complete, human exposure status is “not under control,” there are “insufficient data” for contaminated groundwater status, and the site is not ready for anticipated use (EPA 2017a). The EPA and the Missouri Department of Natural Resources (**MoDNR**) have sampled sediment for heavy metals from the watershed and found arsenic, copper, and lead exceeding “threshold effects levels” (see MacDonald et al. 2000).

Aquatic macroinvertebrates have been found to accumulate elevated concentrations of metals in mine-related streams in Missouri (Besser et al. 1987, 2007; Poulton et al. 2009; Allert et al. 2008, 2009, 2011). Macroinvertebrate communities appear to be negatively affected where elevated concentrations of metals are found in sediment pore water and parameters associated with metals in surface water (Besser et al. 2007, 2009a, 2009b; Brumbaugh et al. 2007; Poulton et al. 2009; Allert et al. 2008, 2011). Metals in pore water generally tracked closely with metals concentrations in sediments, and metals such as cobalt, nickel, lead, and zinc were elevated near mining operations (Brumbaugh et al. 2007). Mine-related effects on macroinvertebrate communities continue to occur in streams near mining areas.

The Madison County Mine Site was added to the Superfund National Priorities List on September 29, 2003, for metals contamination, including lead, in residential soil and within nearby surface water bodies--the Little St. Francis River and its tributaries (EPA 2017b). The primary sources of metals contamination are said to be the large, uncontained tailings and chat piles associated with local historical operations that mined for lead, copper, cobalt, nickel, iron, zinc, silver, and pyrite (EPA 2017b). Tailings dispersal resulted from tailings pond breaks, runoff from piles adjacent to the streams, and human removal.

Logtown Branch is a tributary of LSFR that drains an area associated with the Catherine Mine. Catherine Mine has chat piles that cover approximately 60 acres, and the area has been used as a repository for contaminated yard soils (ATSDR 2005). In 2014, LSFR was placed on the 303(d) List of Impaired Waters for lead in sediment. The listed reach extends from the Logtown Branch confluence downstream to its confluence with the St. Francis River (MoDNR 2016a; MoDNR 2015c). Sources were suggested to be Catherine Mine and Mine LaMotte. The LSFR stations were positioned to evaluate potential influences from Logtown Branch, identify potential influences upstream, possibly associated with Mine LaMotte.

Shays Creek drains part of the Mine LaMotte Tract. This nearly 500 acre tract includes several mines, an abandoned mining area, and the Slime Pond, which is the downstream portion of a tailings impoundment. Mine LaMotte was added to the National Priority List as part of the Madison County Mines Superfund Site in 2003 (MoDNR 2010b). Shays Creek is not on the 303(d) list, but it drains to Village Creek (WBIDs 2863 and 2864), which was placed on the list for inorganic sediment and lead in sediment in 2008. Village Creek has since been removed from the EPA approved 303(d) list in 2010 after completion of the Total Maximum Daily Load (TMDL) for sediment lead and inorganic sediment, which is consistent with 40 CFR §130.7(b) (MoDNR 2010b). Village Creek drains to LSFR downstream of the Fredericktown City Lake.

In this project, Logtown Branch, LSFR, and Shays Creek were examined to determine their ability to support their beneficial use designation of the “protection of warm water aquatic life” (AQL). A stream habitat assessment, biological assessment (including macroinvertebrate community and water quality analyses), surface water dissolved metals analyses, and a total metals characterization of benthic fine sediment were included in this study of Fredericktown area streams.

This biological assessment and metals characterization study was requested by the MoDNR Water Protection Program (WPP). The project was conducted by the Division of Environmental Quality (DEQ), Environmental Services Program (ESP), Water Quality Monitoring Section (WQMS). Laboratory water quality analyses were conducted by the MoDNR Chemical Analysis Section (CAS).

1.2 Objectives

- Assess the stream habitat quality.
- Assess the “protection of warm water aquatic life” designated beneficial use status using the benthic macroinvertebrate community.
- Assess physicochemical water quality.
- Determine the dissolved metals concentrations in the surface water.
- Determine the heavy metals character of the fine sediment in the streams.

1.3 Null Hypotheses

- 1) Stream habitat quality at all streams will be comparable to the stream habitat control.
- 2) Macroinvertebrate Stream Condition Index (MSCI) scores will indicate that Logtown Branch, Little St. Francis River, and Shays Creek are fully supporting of the beneficial use – AQL, and individual biological metrics will be within the optimum scoring range of wadeable/perennial reference stream biological criteria during the fall and spring seasons.
- 3) The biological support categorization for the smaller test streams (Logtown Branch and Shays Creek) will not be influenced by stream size.
- 4) Secondary metrics (dominant macroinvertebrate taxa and EPT taxa compositions) will indicate that Logtown Branch, Little St. Francis River, and Shays Creek

- macroinvertebrate communities are similar to biological criteria reference (**BIOREF**) streams.
- 5) Physicochemical water quality parameters will be within acceptable limits as specified in Missouri's Water Quality Standards (**WQS**; MoDNR 2012b) and will not be notable.
 - 6) Dissolved metals in the surface water will be within acceptable hardness-dependent limits outlined in Missouri's WQS (MoDNR 2014) in Logtown Branch, Little St. Francis River, and Shays Creek stations.
 - 7) Total metals (i.e. arsenic, cadmium, copper, lead, nickel, silver, or zinc) concentrations associated with benthic fine sediment will be below potentially toxic threshold levels in Logtown Branch, Little St. Francis River, and Shays Creek.

2.0 Methods

Kenneth B. Lister, Dave Michaelson, Raissa Espejo, Dave Gullic, and other ESP personnel were involved in all or some aspects of this study. Methods and study timing are outlined in this section. The study area and station descriptions, Ecological Drainage Units, and land uses are provided. Stream habitat assessment procedures are discussed. Biological assessment procedures that include macroinvertebrate and physicochemical water collection methods and analyses are discussed in this section. Surface water and benthic fine sediment collection methods are provided.

2.1 Study Timing

Sampling was conducted in the fall of 2015 and the spring of 2016. Stream habitat assessments were conducted at Shays Creek and Hunter Creek in Wayne County (a habitat assessment control station), on September 21, 2015. Habitat assessments were conducted on Logtown Branch and LSFR stations on September 22, 2015. Macroinvertebrate, water, and fine sediment samples were collected at Shays Creek on September 21, 2015, and at Logtown Branch and LSFR stations on September 22, 2015. Spring macroinvertebrate and water samples were collected at Shays Creek on March 15, 2016, and on March 16, 2016, at Logtown Branch and LSFR stations.

2.2 Study Area, Station Locations, and Descriptions

The study areas and stations are located within the Ozark/Upper St. Francis/Castor Ecological Drainage Unit (Figure 1). Five stations were allocated for the three study streams (Figure 2; Table 1). One station in Logtown Branch was located approximately 40 yards upstream of its confluence with LSFR. Two stations on LSFR bracket Logtown Branch, one station upstream and the other downstream of the Logtown Branch confluence. Two stations were allocated for Shays Creek. One station on Shays Creek was located immediately downstream of the Slime Pond, and the other was upstream of the confluence with Village Creek. The length of each study area was approximately 20 times the average width, which is consistent with the *Semi-Quantitative Macroinvertebrate Stream Bioassessment Project Procedure (SMSBPP; MoDNR 2012a)*.

Table 1
Locations and Descriptions of Stations in the Fredericktown Area Study, 2015-2016

Station	County	Location	Description; WBID	Purpose; Class
Little St. Francis River #2	Madison	NW sec. 36, T. 34 N., R. 06 E. E735697 N4165843	Upstream of confluence with Logtown Branch; WBID 2854	Test; P
Logtown Branch #1	Madison	NW sec. 36, T. 34 N., R. 06 E. E 735694 N4165565	Upstream of confluence with Little St. Francis River; WBID U2854	Test; U
Little St. Francis River #1	Madison	NW sec. 36, T. 34 N., R. 06 E. E735761 N4165638	Downstream of confluence with Logtown Branch; WBID 2854	Test; P
Shays Creek #2;	Madison	SW sec. 33, T. 34 N., R. 07 E. E740808 N4164973	Downstream of Slime Pond; WBID 2865	Test; C
Shays Creek #1;	Madison	Survey 3086, T. 33 N., R. 07 E. E739680 N4162989	Upstream of confluence with Village Creek; WBID 2865	Test; C
Hunter Creek #1	Wayne	NE sec. 20, T. 30 N., R. 06 E. E729819 N4127313	Downstream of headwater confluence; west boundary of MDC Coldwater CA; WBID 2841	Candidate Reference; SHAPP Control; C

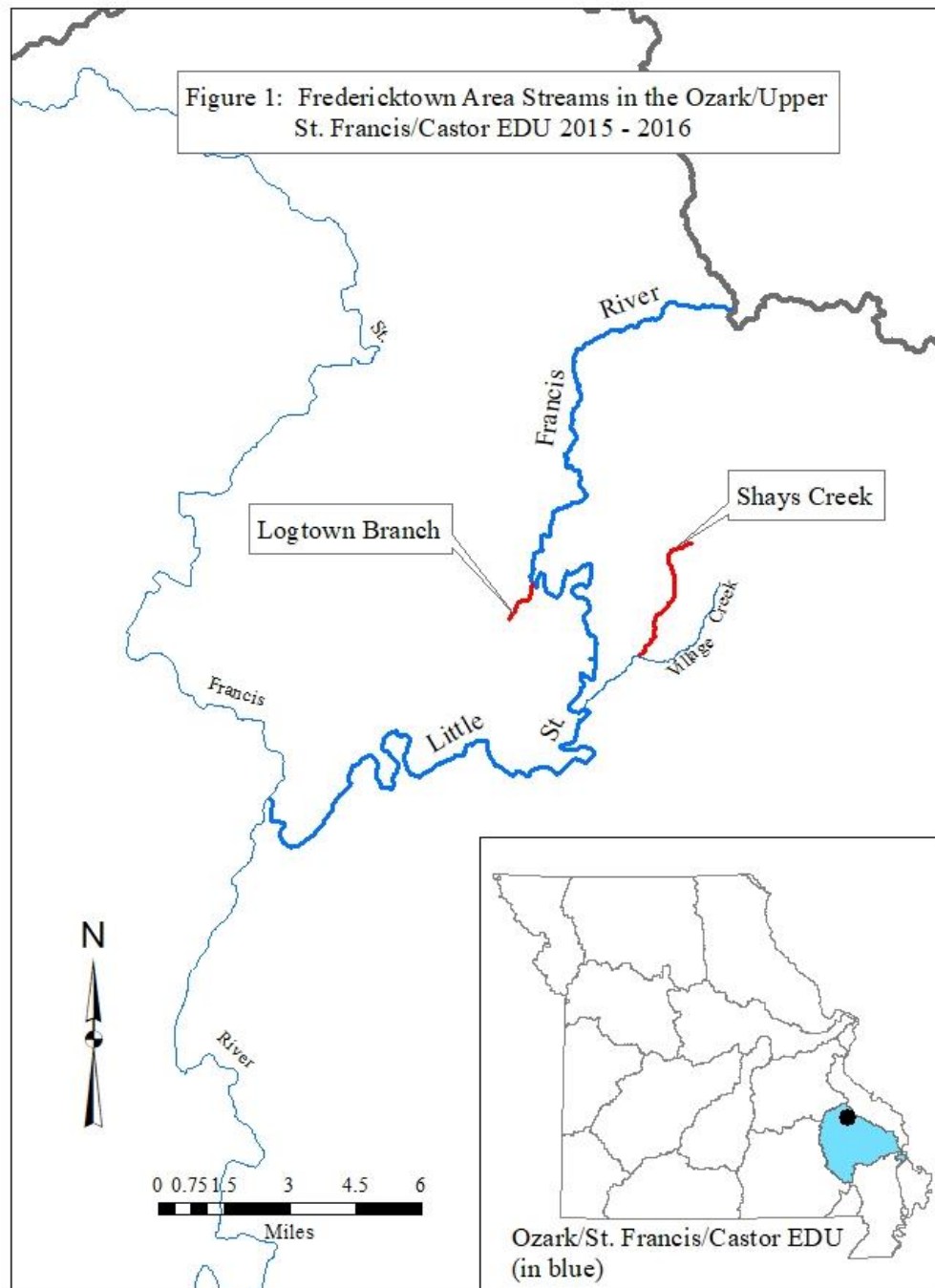
WBID=Water Body ID; P=Permanent, C=Intermittent, U=Unclassified; SHAPP=Stream Habitat Assessment Project Procedure (MoDNR 2016c); CA=Conservation Area

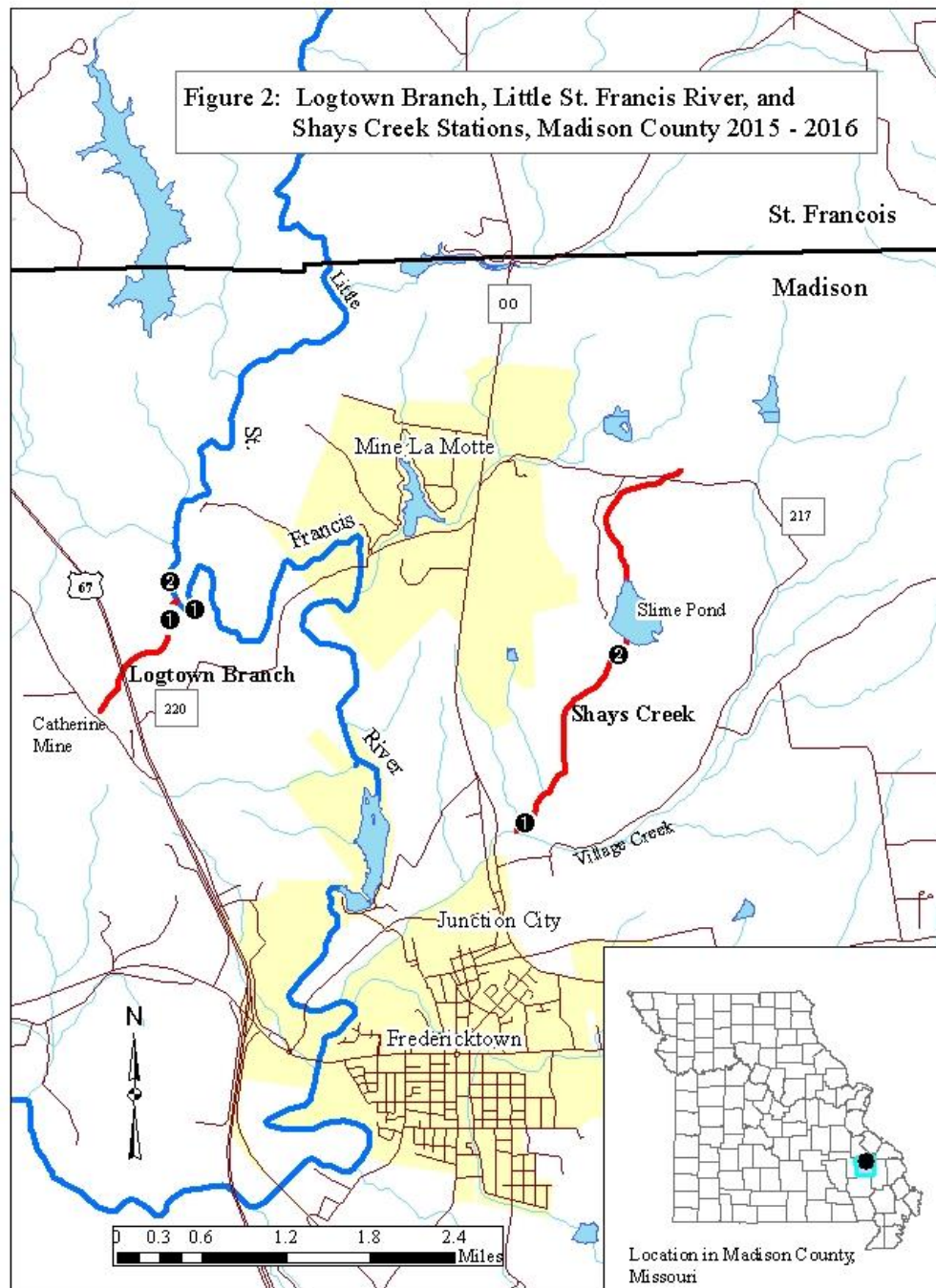
2.2.1 Ecological Drainage Unit

The Fredericktown area streams are located in the Ozark/Upper St. Francis/Castor Ecological Drainage Unit (EDU; Figure 1). An EDU is an area that is delineated and identified by its natural terrestrial physiographic division and major riverine watershed components. EDUs are described in detail by Sowa et al. (2007). Streams of similar size within an EDU are expected to contain similar habitat conditions and biological communities. As such, stream habitat, biological, and physicochemical components should be comparable between test streams and reference streams within the same EDU.

2.2.2 Land Use Description

Land uses in close proximity to the Fredericktown area streams were examined (Table 2). Land uses were identified for each station based on the associated 12-digit Hydrological Unit Code (HUC-12) area. The percent land use data were derived from Thematic Mapper satellite data collected between 2000 and 2004 and interpreted by the Missouri Resource Assessment Partnership (MoRAP). Land uses were compared by percentage among stations and with the overall EDU. The dominant land use was forest at all Fredericktown area stations and in the EDU, although the Fredericktown area percentages were approximately 10 to 15 percent lower than the EDU (Table 2). Grassland was the second most abundant land use at all





stations and was approximately 10 percent higher than the EDU. The percentage of cropland was slightly lower than the EDU at all stations. Woody/herbaceous vegetation was more abundant at test stations than in the EDU. Urban land use was very low at all stations and the EDU. Similar dominance of land uses (slightly lower cropland, slightly higher woody/herbaceous vegetation, and very low urban influences) suggest that land use should not interfere with interpretation of results.

Table 2
 Percent Land Use/Cover for Logtown Branch, Little St. Francis River (LSFR), Shays Creek
 Stations (HUC-12) and the Ozark/St. Francis/Castor EDU

Stations/ Land-Use	LSFR #2	Logtown Branch #1	LSFR #1	Shays Creek #2	Shays Creek #1	EDU
<i>HUC-12 080202020</i>	<i>-101</i>	<i>-101</i>	<i>-101</i>	<i>-102</i>	<i>-102</i>	
Impervious	0.7	0.7	0.7	2.5	2.5	0.7
Urban	1.0	1.0	1.0	3.9	3.9	1.0
Barren	0.5	0.5	0.5	2.3	2.3	0.3
Cropland	2.4	2.4	2.4	1.1	1.1	8.1
Grassland	34.3	34.3	34.3	33.0	33.0	23.2
Forest	45.7	45.7	45.7	47.5	47.5	59.7
Woody/Herbaceous	12.7	12.7	12.7	7.9	7.9	3.7
Wetland	1.0	1.0	1.0	0.4	0.4	1.5
Open-water	1.6	1.6	1.6	1.4	1.4	1.9

2.3 Stream Habitat Assessment Project Procedure

The standardized *Stream Habitat Assessment Project Procedure (SHAPP)* was followed as described for riffle/pool prevalent streams (MoDNR 2016c). According to the SHAPP, stream habitat is a factor that can affect the quality of the biological community. Stream habitat quality of test streams is compared to the habitat quality of a control stream (SHAPP control) as a measure of similarity. Stream habitat features are given numeric scores for the SHAPP control and the test stations based on visual assessments. The SHAPP score for each Fredericktown area station is then expressed as a percentage of the SHAPP control. If the SHAPP score for a test station is $\geq 75\%$ of the control score, the stream habitat at that test station is considered to be comparable to the habitat of the control. Hunters Creek in Wayne County (WBID 2841) served as a SHAPP control for this study (Table 1).

2.4 Biological Assessment

This biological assessment was conducted as described in the SMSBPP (MoDNR 2012a). A biological assessment involves examination of the macroinvertebrate community biological metrics and physicochemical water results. Primary metrics are numeric descriptions of the macroinvertebrate community structure that ultimately assess the stream's ability to support its beneficial use designation. Secondary metrics are used to further illustrate and explain differences in the macroinvertebrate communities that may also identify possible sources of influence. Water quality constituents are examined for trends, notable results, and compared to

Missouri's Water Quality Standards (MoDNR 2012b) as well as other available thresholds. Biological assessments are grouped by year and station.

2.4.1 Macroinvertebrate Sampling, Identification, and Analyses: Primary Metrics

Macroinvertebrate samples were collected from multiple habitats, as described in the SMSBPP (MoDNR 2012a). Fredericktown area stations are considered to be riffle/pool dominant streams. As such, coarse substrate (**CS**; riffle), non-flowing water over depositional substrate (**NF**), and rootmat (**RM**) habitats were sampled. In the WQMS laboratory, macroinvertebrates were acquired from subsamples of the benthic material collected for each habitat as described in the SMSBPP (MoDNR 2012a). These macroinvertebrates were then identified to specific taxonomic levels (MoDNR 2016d) to provide for consistent and accurate determination of a stream's ability to support the "protection of aquatic life" (AQL) designated beneficial use category. Primary metrics generated from these macroinvertebrate data are used to calculate the Macroinvertebrate Stream Condition Index (**MSCI**). Ultimately, this MSCI and the narrative will define the test stream's ability to support the designated beneficial use for the protection of aquatic life.

A stream condition index using macroinvertebrates was developed as a measurement of a stream's biological integrity (Rabeni et al. 1997). The index was further refined to include biological criteria that were generated using wadeable/perennial biological reference streams (**BIOREF**) for each EDU, as described in *Biological Criteria for Perennial/Wadeable Streams* (MoDNR 2002). Now called the Macroinvertebrate Stream Condition Index, this semi-quantitative rank score is derived by comparing test station metric values to BIORREF criteria.

An MSCI score is developed by compiling rank metric scores that are calculated for individual biological metric values. The four primary biological metrics used to calculate the MSCI are 1) Taxa Richness (**TR**), 2) Ephemeroptera/Plecoptera/Trichoptera Taxa (**EPTT**), 3) Biotic Index (**BI**), and 4) Shannon Diversity Index (**SDI**). Each metric value is compared to the BIORREF criteria (Tables 4a and 5a). Metrics then receive individual scores of 5, 3, or 1 based on the BIORREF scoring range. The sum of all four individual metric scores is the MSCI score, which is calculated for each station. The MSCI scores are interpreted as follows: 20-16 = fully supporting; 14-10 = partially supporting; and 8-4 = non-supporting of the AQL beneficial use designation. MSCI scores were examined by station and grouped by year (Tables 4a and 5a).

Individual metric scores are usually evaluated to determine how each metric contributed to the MSCI score. Individual biological metric values and scores may also be used to evaluate changes in community composition among stations or streams. Variations in certain metric values and scores may aid in identifying types and sources of impairment.

2.4.2 Candidate Reference Criteria: Stream Size Influence

Logtown Branch and Shays Creek are smaller than most BIORREF streams used to generate biological criteria. Stream size can affect the macroinvertebrate community composition and thus the biological support category generated using larger wadeable/perennial BIORREF criteria on small streams. To address the potential effects that stream size may have on the biological support categorization, Logtown Branch and Shays Creek metric values were compared to

criteria calculated using macroinvertebrate data from smaller candidate reference streams in the Ozark/Upper St. Francis/Castor EDU (Tables 4b and 5b). If the original biological support categorization changes to a different category (e.g. from partial to full support), it will be assumed that stream size may have had an effect on the macroinvertebrate community composition.

2.4.3 Macroinvertebrate Analyses: Secondary Metrics

Secondary metrics are used to highlight or further analyze findings of the primary metrics and may assist in identifying sources of impairment. Two secondary metrics were used. The Dominant Macroinvertebrate Taxa (DMT) was used according to the SMSBPP (MoDNR 2012a) and Ephemeroptera, Plecoptera, and Trichoptera taxa were examined between BIOREF streams and test streams, as well as among stations for each season.

The DMT metric is a comparison between BIOREF communities and test stations based on abundance. The DMT metric lists the top 10 most abundant taxa in BIOREF streams and test streams. DMT of test streams are then compared that of BIOREF stations within the same EDU as the test streams. A DMT that is absent or ranked outside the top 10 (i.e. substantially reduced, ranked lower) may suggest that a stressor is influencing its presence. A majority of DMT in similar abundance between a test station and the BIOREFs suggests there are no or few stressors. Few DMT common to a test station and the BIOREFs suggests that there may be stressors shaping the community composition. Changes in presence or abundance of DMT among stations may identify areas of interest.

The Ephemeroptera, Plecoptera, and Trichoptera (EPT) taxa richness comparisons were made between BIOREF streams and test stations, as well as among test stations. The taxa richness within each order should be similar between streams and stations if stressors are not present. The composition of each EPT order was also evaluated. EPT taxa richness and composition may identify areas of interest, as well as taxa that are sensitive or tolerant to stressors.

A complete taxa list is provided in Appendix A. The *Macroinvertebrate Database Bench Sheet Report* may be used to further examine species occurrence. The bench sheet report is grouped by season and station.

2.4.4 Physicochemical Water Sampling and Analyses

Physicochemical water samples were collected and analyzed according to the applicable MoDNR, ESP Standard Operating Procedures (SOPs). Results for physicochemical water variables were examined by year and station.

Physicochemical water constituents were measured in the field or analyzed at the ESP environmental laboratory in Jefferson City, Missouri. Water was sampled according to the SOP MDNR-ESP-001 *Required/Recommended Containers, Volumes, Preservatives, Holding Times, and Special Sampling Considerations* (MoDNR 2016b). Temperature (°C), pH, conductivity (µS/cm), dissolved oxygen (mg/L), and discharge (cubic feet per second-**cfs**) were measured *in situ*. The ESP's CAS conducted analyses for ammonia as nitrogen (NH₃-N; mg/L), nitrate+nitrite as nitrogen (NO₃+NO₂-N; mg/L), total nitrogen (TN; mg/L), chloride (Cl; mg/L), sulfate

(**SO₄**; mg/L), total phosphorus (**TP**; mg/L), non-filterable residue (**NFR**; mg/L). Turbidity (nephelometric turbidity units, **NTU**) was measured and recorded in the WQMS biology laboratory. All samples to be analyzed at ESP were kept on ice during transport.

Surface water physicochemical results were compared to Missouri's Water Quality Standards (MoDNR 2012b) and suggested guidelines, or they were highlighted if results were notable among stations. Because Missouri does not currently have nutrient criteria for streams and rivers, nutrient values were compared to suggested guidelines as outlined by the *Ambient Water Quality Criteria Recommendations for Rivers and Streams in Nutrient Ecoregion XI* (EPA 2000). The EPA *Aggregate Nutrient Ecoregion XI, level III ecoregion 39* recommended reference values used for comparison were as follows: NO₃+NO₂-N (0.239 mg/L), turbidity (1.425 NTU), TN (0.379 mg/L), and TP (0.006625 mg/L).

2.4.5 Discharge

Stream discharge was measured using a Marsh-McBirney Flowmate 2000™ flow meter at each station. Velocity and depth measurements were recorded at each station, and discharge was calculated according to SOP MDNR-ESP-113 *Flow Measurement in Open Channels* (MoDNR 2015b).

2.5 Surface Water: Dissolved Metals

Surface water samples were analyzed for dissolved metals content by ESP's CAS. Water grab samples were filtered using a 0.45 µm filter, preserved, and handled as outlined in MDNR-ESP-001 (MoDNR 2016b). Dissolved metals included in this project were arsenic (**As**), barium (**Ba**), cadmium (**Cd**), calcium (**Ca**), cobalt (**Co**), copper (**Cu**), Iron (**Fe**), lead (**Pb**), magnesium (**Mg**), manganese (**Mn**), nickel (**Ni**), silver (**Ag**), and zinc (**Zn**). Hardness as CaCO₃ values were calculated using Ca and Mg according to the American Public Health Association (APHA 2012) Standard Methods (2340 B, 2011). Results were compared to hardness dependent chronic and acute toxicity thresholds for heavy metals described in Missouri's Water Quality Standards (MoDNR 2014). These limits are based on lethality of a toxicant given long-term (chronic toxicity) or short-term (acute toxicity) exposure. Metals concentrations among stations may also identify intermittent or continuous influences, as well as longitudinal trends.

2.6 Fine Sediment: Total Metals Characterization

Instream deposits of benthic fine sediment (i.e. particle size <2 mm) were collected and analyzed for total recoverable metals content by ESP's CAS. Fine sediments were analyzed for total recoverable As, Cd, Cu, Pb, Ni, Ag and Zn. Notable results are those that exceed or are near threshold concentrations determined by MacDonald et al (2000) or MacDonald and MacFarlane (1999) for individual metals (PEC, PEQ), or concentrations published in MacDonald et al. (2009) for effects from a mixture or combination of these metals ($\sum \text{PEQ}_{\text{Cd, Pb, Zn}}$ and mean $\text{PEQ}_{\text{metals}}$).

Fine sediment was collected from all stations in the fall of 2015. A 2-ounce glass jar was used to dredge fine sediment from the substrate no deeper than 2 inches. Three 2-ounce samples were composited into one 8-ounce glass jar. Fine sediment (<2.0 mm) was subsampled from the

8-ounce jar and analyzed for total metals concentrations ($\mu\text{g/kg}$) by ESP's CAS. Individual total metals concentrations and mixture or combination of metals quotients were compared to threshold levels (mg/kg).

Individual metals concentrations were compared to Probable Effects Concentrations (**PECs**; MacDonald et al. 2000). A PEC is a threshold level for a contaminant, above which harmful effects are likely to be observed. MacDonald et al. (2000) found PECs to be reliable for 10 metals (including cadmium, lead, and zinc) in classifying sediments as potentially toxic or nontoxic to sediment-dwelling organisms. The PEC for arsenic = 33.9 mg/kg ; cadmium = 4.98 mg/kg ; copper = 149 mg/kg ; lead = 128 mg/kg ; nickel = 48.6 mg/kg ; silver = 2.2 mg/kg^* ; and zinc = 459 mg/kg (MacDonald et al. 2000; *MacDonald and MacFarlane 1999).

Individual metals were also examined using a Probable Effects Concentration Quotient (**PEQ**; MacDonald et al. 2000, 2009; Ingersoll et al. 2001, 2002, 2009; Besser et al. 2008, 2009a). A PEQ is the total recoverable metal concentration divided by the PEC threshold for that metal (MacDonald et al. 2000). A PEQ greater than 1.0 may indicate an increased risk of toxicity due to the concentration of that metal (Besser et al. 2009a).

Individual metals concentrations may be compared to the Tri-State Mining District (**TSMD**; MacDonald et al. 2009) site specific thresholds (**T₁₀**) to further assess the potential risk of toxicity to benthic invertebrates. A concentration above a T₁₀ value corresponds to a 10 percent reduction in the control-adjusted survival or biomass of amphipods, midges, or mussels compared to the average response rate for toxicity test organisms exposed to reference sediments. The TSMD threshold (T₁₀) for cadmium = 11.1 mg/kg , lead T₁₀ = 150 mg/kg , and zinc T₁₀ = 2083 mg/kg .

The toxic effects from a mixture or combination of metals may be examined using the sum of PEQs for cadmium, lead, and zinc ($\sum \text{PEQ}_{\text{Cd, Pb, Zn}}$) or the mean PEQ for all metals (**mean PEQ_{metals}**). The $\sum \text{PEQ}_{\text{Cd, Pb, Zn}}$ is the sum of PEQs that identifies potential toxicity due to the mixture or combination of these metals (Ingersoll et al. 2001; Besser et al. 2009a, 2009b; MacDonald et al. 2000, 2009; Allert et al. 2011). The mean PEQ_{metals} is suggested to normalize the sample result (Long et al. 1998; MacDonald et al. 2000, 2009; Ingersoll et al. 1998, 2001, 2002, 2009; Besser et al. 2008, 2009b). The mean PEQ_{metals} is the $\sum \text{PEQs}$ for all metals divided by the number of metals included in the mixture ($n = 7$). Although the $\sum \text{PEQ}$ and the mean PEQ are included for comparison, both are individually effective in predicting potential toxicity due to a mixture or combination of metals. The T₁₀ used for $\sum \text{PEQ}_{\text{Cd, Pb, Zn}} = 7.92$ and the mean PEQ_{metals} = 1.11 (MacDonald et al. 2009). Quotients above these thresholds suggest the mixture or combination of metals associated with the fine sediment is likely to be toxic to the benthic-dwelling macroinvertebrate community.

2.7 Quality Control

Quality assurance for this study is outlined in the FY 2016 Quality Assurance Project Plan (**QAPP**). Quality control procedures were conducted in accordance with applicable MoDNR SOPs and the SMSBPP (MoDNR 2012a). A duplicate macroinvertebrate sample was collected at

one station among all of this team's field assignments during each sample season. Duplicate samples were compared using the Quality Similarity Index (**QSI**). This index is a means of gauging consistency between the sample collectors, as well as the accuracy in taxa identification. Duplicate surface water and fine sediment samples were collected and analyzed for every 10 samples to assess consistency and accuracy in collection and analyses. However, no duplicate macroinvertebrate or water chemistry samples were collected in this study.

3.0 Results

Results from stream habitat assessments, biological assessments, surface-water dissolved metals, and total metals character of the benthic fine sediments are presented in this section. Notable results or trends are highlighted for each section. Results are grouped by year and station.

3.1 Stream Habitat Assessment

Stream habitat in Logtown Branch #1 was not comparable to the SHAPP control (Table 3). The station reached 71 percent of the SHAPP control, which is below the ≥ 75 percent comparable range. Habitat factors that contributed to the less than optimal score at Logtown Branch included fewer velocity/depth regimes, lower channel flow status, riffle quality, bank stability, less vegetative protection riparian vegetation compared to the control site.

The quality of stream habitat varied in LSFR. The LSFR #2 SHAPP score reached 72 percent of the control site and was not comparable to the SHAPP control. All habitat factors contributed to the lower percentage, but several were more notable. The station had much less epifaunal substrate, more sediment deposition, lower bank stability, less vegetative protection and riparian vegetation than the SHAPP control. Stream habitat at LSFR #1 was comparable to the SHAPP control with a 77 percent similarity. LSFR #1 stream habitat factors were similar to the upstream LSFR #2 station with two exceptions; the downstream station had more epifaunal substrate and better bank stability.

Stream habitat at Shays Creek was less than comparable to the SHAPP control (Table 3). The Shays Creek #2 was 63 percent of the SHAPP control score. Substantial differences were due to less epifaunal substrate, fewer velocity/depth regimes, higher sediment deposition, lower channel flow status, lower riffle quality, and narrow wooded riparian zone. The Shays Creek #1 score was 59 percent of the SHAPP control. The station had substantially fewer velocity/depth regimes, much higher sediment deposition, lower channel flow status, lower riffle quality, and less wooded riparian zone. Stream habitat was generally similar between the upstream and downstream Shays Creek stations.

Table 3
 Stream Habitat Assessment Project Procedure (SHAPP) Scores for
 Comparison with SHAPP Control Stream

Habitat Assessment Factor	LSFR #2	Logtown Br. #1	LSFR #1	Shays Cr. #2	Shays Cr. #1	SHAPP Control
Epifaunal Substrate	7	17	15	13	16	18
Embeddedness	17	17	14	13	13	14
Velocity/Depth Regime	16	6	16	10	7	15
Sediment Deposition	2	13	3	3	4	20
Channel Flow Status	14	7	14	10	7	19
Channel Alteration	18	18	19	18	18	20
Riffle Quality	11	6	6	10	10	19
Bank Stability L/R	2/9	8/7	10/9	9/9	9/9	9/9
Vegetative Protection L/R	1/6	1/1	3/2	6/4	1/1	4/2
Riparian Vegetation L/R	10/9	9/10	10/9	1/1	1/3	10/10
Score	122	120	130	107	99	169
Percentage of SHAPP control	72	71	77	63	59	--

Bold = Below 75 percent threshold; L = Left bank, R = Right bank

3.2 Biological Assessment

Biological assessments consist of macroinvertebrate community primary and secondary metric analyses, as well as general water quality analyses. Notable results for Fredericktown area streams are grouped by season and station.

3.2.1 Macroinvertebrate Community Analyses: Primary Metrics

Primary metrics, such as the MSCI, biological support category, and individual metric values and scores were examined for all Fredericktown area streams. Smaller test streams (Logtown Branch and Shays Creek) were compared to candidate reference criteria to assess whether differences in the macroinvertebrate community exist due to stream size. Results are grouped by season and subdivided by stream and station in the fall and spring seasons.

Fall

Logtown Branch had a fully supporting MSCI score of 16 in fall 2015 (Table 4a). Two individual metric values detracted from the MSCI with scores of 3. The EPTT value (16) was 8 taxa below the optimum threshold value (>23). The BI (6.7) was 0.9 higher than the optimum threshold value (<5.9).

Although LSFR stations had only slightly different MSCI scores in fall 2015, they were in different support categories (Table 4a). The upstream station LSFR #2 had a fully supporting MSCI score of 16. Two individual metric values were below the fully supporting threshold. The EPTT metric value (21) was below the optimum threshold value (>23). The BI (6.2) was slightly higher than the optimum threshold value (<5.9). The downstream station, LSFR #1, attained a partially supporting MSCI score of 14. The EPTT (22) was slightly below the optimum (>23), and the BI (6.0) was slightly higher than the optimum (<5.9). The SDI (3.36) tied with the threshold value (>3.36), resulting in a suboptimal score. Metric values were similar between LSFR stations.

Both Shays Creek stations had partially supporting MSCI scores in fall 2015 (Table 4a). Shays Creek #2 had an MSCI score of 10 and Shays Creek #1 had an MSCI score of 14. All individual metrics were suboptimal at station #2. The TR (77) was 10 taxa below the optimum threshold value (>86). The EPTT (9) was much lower than the optimum threshold value (>23), which resulted in the non-supporting score for this metric. The BI (6.8) was higher than the optimum (<5.9) and the SDI (3.18) value was lower than the optimum (>3.36). At Shays Creek #1, three of the four biological metrics were suboptimal. The TR (78) was 9 below the optimum (>86). The EPTT (17) was nearer the optimum (>23) than Shays Creek #2 but attained a score of 3. The BI (6.3) was higher than the optimum range (<5.9). The SDI was the only Shays Creek #1 metric to achieve the optimum score of 5. Metric values were generally closer to optimum at the downstream Shays Creek station.

Table 4a

Logtown Branch, Little St. Francis River (LSFR), and Shays Creek Stations, Fall 2015 –
 Biological Reference Stream (BIOREF) Criteria, Individual Metric Values and Scores,
 Macroinvertebrate Stream Condition Index Scores (MSCI) and Support Category by Station;
 BIOREF Criteria Scoring Table (bottom in gray) – Used to calculate metric scores

Stream and Station Number	Sample No.	TR	EPTT	BI	SDI	MSCI	Support
LSFR #2	15039	102 ₍₅₎	21 ₍₃₎	6.2 ₍₃₎	3.59 ₍₅₎	16	F
Logtown Branch #1	15038	95 ₍₅₎	16 ₍₃₎	6.7 ₍₃₎	3.75 ₍₅₎	16	F
LSFR #1	15037	96 ₍₅₎	22 ₍₃₎	6.0 ₍₃₎	3.36 ₍₃₎	14	P
Shays Creek #2	15034	77 ₍₃₎	9 ₍₁₎	6.8 ₍₃₎	3.18 ₍₃₎	10	P
Shays Creek #1	15035	78 ₍₃₎	17 ₍₃₎	6.3 ₍₃₎	3.47 ₍₅₎	14	P
Metric Score=5	↔	>86	>23	<5.9	>3.36	20-16	Full
Metric Score=3	↔	86-43	23-11	5.9-7.9	3.36-1.68	14-10	Partial
Metric Score=1	↔	<43	<11	>7.9	<1.68	8-4	Non

BIOREF Scoring Table (bottom) developed from BIOREF streams ($n=11$); TR=Taxa Richness; EPTT=Ephemeroptera, Plecoptera, Trichoptera Taxa; BI=Biotic Index; SDI=Shannon Diversity Index; (#subscript)=Individual metric score; **Bold**=less than optimum value and score.

Spring

Logtown Branch received a partially supporting MSCI score of 12 in the spring of 2016 (Table 5a). All individual metric values had suboptimum scores of 3. The TR (76) was well below the optimum threshold value (>95). The EPTT (21) was 9 taxa lower than the optimum threshold value (>29). The BI (6.2) was 0.4 higher than the optimum (<5.9). The SDI (2.72) was substantially lower than optimum (>3.61).

Little St. Francis River #2 attained a fully supporting MSCI score of 16. Suboptimal metrics included the BI (5.9), which tied the threshold value (<5.9), and the SDI (3.55) was slightly below the optimum (>3.61). LSFR #1 received a partially supporting MSCI score of 14. Metric values that contributed to the less than optimum MSCI included TR (95), which had 1 fewer taxon than the optimum range (>95). The BI (6.1) was 0.3 above the optimum range (<5.9), scoring 3. The SDI (3.35) was below the optimum range (>3.61), and it also received a metric score of 3. Metric values tended to be closer to optimum at the upstream station.

Shays Creek #2 and Shays Creek #1 received partially supporting MSCI scores of 12 in spring (Table 5a). All metric values contributed to the less than optimum metric scores of 3 at both stations. At Shays Creek #2, the TR (81) was 15 taxa below the optimum criterion (>95). The EPTT (16) was substantially below the optimum range (>29). The BI (6.2) was slightly higher than optimum (<5.9). The SDI (3.20) was 0.42 below the optimum (>3.61). At Shays Creek #1, the TR (83) was well below the optimum range (>95). The EPTT (18) was much lower than the

optimum range (>29). The SDI (3.35) was below the optimum range (>3.61). Metric values were generally similar between stations; however, the downstream station #1 had slightly higher TR, EPTT, SDI, and lower BI values.

Table 5a
 Logtown Branch, Little St. Francis River (LSFR), and Shays Creek Stations, Spring 2016 –
 Biological Reference Stream (BIOREF) Criteria, Individual Metric Values and Scores,
 Macroinvertebrate Stream Condition Index Scores (MSCI) and Support Category by Station;
 BIOREF Criteria Scoring Table (bottom in gray) – Used to calculate metric scores

Stream and Station Number	Sample No.	TR	EPTT	BI	SDI	MSCI	Support
LSFR #2	16006	112 ₍₅₎	35 ₍₅₎	5.9 ₍₃₎	3.55 ₍₃₎	16	F
Logtown Branch #1	16005	76 ₍₃₎	21 ₍₃₎	6.2 ₍₃₎	2.72 ₍₃₎	12	P
LSFR #1	16004	95 ₍₃₎	31 ₍₅₎	6.1 ₍₃₎	3.35 ₍₃₎	14	P
Shays Creek #2	16000	81 ₍₃₎	16 ₍₃₎	6.2 ₍₃₎	3.20 ₍₃₎	12	P
Shays Creek #1	16001	83 ₍₃₎	18 ₍₃₎	6.0 ₍₃₎	3.35 ₍₃₎	12	P
Metric Score=5	↔	>95	>29	<5.9	>3.61	20-16	Full
Metric Score=3	↔	95-47	29-15	5.9-7.9	3.61-1.81	14-10	Partial
Metric Score=1	↔	<47	<15	>7.9	<1.81	8-4	Non

BIOREF Scoring Table (bottom) developed from BIOREF streams ($n=14$); TR=Taxa Richness; EPTT=Ephemeroptera, Plecoptera, Trichoptera Taxa; BI=Biotic Index; SDI=Shannon Diversity Index; (#subscript)=Individual metric score; **Bold**=less than optimum value and score.

3.2.2 Candidate Reference Comparison: Stream Size Influence

Logtown Branch and Shays Creek are smaller streams than the MoDNR BIOREF wadeable-perennial streams of the EDU. To determine if stream size had an effect on the macroinvertebrate community composition and the original biological support categorization, metric values were compared to candidate reference stream criteria calculated using data from smaller (similar-size) reference quality streams in the Ozark/Upper St. Francis/Castor EDU (Tables 4b and 5b). A change in support category from the original suggests stream size influenced the macroinvertebrate community and MSCI. Biological criteria calculated using small candidate reference streams had lower threshold values for TR, EPTT, and BI in both seasons, whereas the SDI threshold was higher in the fall and lower in the spring than the BIOREF stream criteria.

Fall

Logtown Branch and Shays Creek metric values were compared to candidate reference criteria for fall (Table 4b). The metric scores, MSCI scores, and biological support category did not change. As a result, Logtown Branch remained in the fully supporting category, and both Shays Creek stations remained in the partially supporting category. Stream size did not appear to have an effect on the macroinvertebrate community composition at either stream in the fall.

Table 4b

Candidate Reference (Similar-size) Stream Biological Criteria, Individual Metric Values and Scores, Δ Macroinvertebrate Stream Condition Index (MSCI) Scores, and Δ Biological Support Categories for Logtown Branch and Shays Creek Stations, Fall 2015

Stream and Station Number	Sample No.	TR	EPTT	BI	SDI	Δ MSCI	Δ Support
Logtown Branch #1	15038	95 ₍₅₎	16 ₍₃₎	6.7 ₍₃₎	3.75 ₍₅₎	16	F _(NC)
Shays Creek #2	15034	77 ₍₃₎	9 ₍₁₎	6.8 ₍₃₎	3.18 ₍₃₎	10	P _(NC)
Shays Creek #1	15035	78 ₍₃₎	17 ₍₃₎	6.3 ₍₃₎	3.47 ₍₅₎	14	P _(NC)
Metric Score=5	↔	>79	>21	<4.9	>3.40	20-16	Full
Metric Score=3	↔	79-39	21-11	4.9-7.3	3.40-1.70	14-10	Partial
Metric Score=1	↔	<39	<11	>7.3	<1.70	8-4	Non

Metric Scoring Table (in light gray) developed using small candidate reference stream samples ($n=7$). TR=Taxa Richness; EPTT=Ephemeroptera, Plecoptera, Trichoptera Taxa; BI=Biotic Index; SDI=Shannon Diversity Index; (#subscript) = Individual metric score; **Bold** = change; NC= no change in support category.

Spring

Logtown Branch and Shays Creek metric values were compared to candidate reference criteria for spring (Table 5b). The Logtown Branch MSCI and support category did not change from the original suggesting stream size was not an influence. However, the MSCI scores and support categories at both Shays Creek stations changed from partial to fully supporting. TR and SDI metric scores increased from 3 to 5 at both stations, which resulted in increased MSCI scores from 12 to 16 and changes in their support categories. It appears that stream size may have contributed to the macroinvertebrate community composition of Shays Creek in the spring.

Table 5b

Candidate Reference (Similar-size) Stream Biological Criteria, Individual Metric Values and Scores, Δ Macroinvertebrate Stream Condition Index (MSCI) Scores, and Δ Biological Support Categories for Logtown Branch and Shays Creek Stations, Spring 2016

Stream and Station Number	Sample No.	TR	EPTT	BI	SDI	Δ MSCI	Δ Support
Logtown Branch #1	16005	76 ₍₃₎	21 ₍₃₎	6.2 ₍₃₎	2.72 ₍₃₎	12	P _(NC)
Shays Creek #2	16000	81 _(3→5)	16 ₍₃₎	6.2 ₍₃₎	3.20 _(3→5)	12→16	P→F
Shays Creek #1	16001	83 _(3→5)	18 ₍₃₎	6.0 ₍₃₎	3.35 _(3→5)	12→16	P→F
Metric Score=5	↔	>80	>27	<4.9	>3.10	20-16	Full
Metric Score=3	↔	80-40	27-13	4.9-7.3	3.10-1.55	14-10	Partial
Metric Score=1	↔	<40	<13	>7.3	<1.55	8-4	Non

Metric Scoring Table (in light gray) developed using small candidate reference stream samples ($n=10$). TR=Taxa Richness; EPTT=Ephemeroptera, Plecoptera, Trichoptera Taxa; BI=Biotic Index; SDI=Shannon Diversity Index; (#subscript) = Individual metric score; **Bold** = change; NC= no change in support category.

3.2.3 Macroinvertebrate Community Analyses: Secondary Metrics

The dominant macroinvertebrate taxa metric (DMT) was used to examine the community composition of the Fredericktown area stations (Tables 6 and 7). EPT taxa richness was compared between BIOREF streams and test stations, as well as among test stations (Appendix A). Results are grouped by season.

3.2.3.1 Dominant Macroinvertebrate Taxa

The top 10 DMT from BIOREF streams were compared to the DMT list for Logtown Branch, LSFR #2 and #1, and Shays Creek #2 and #1. The BIOREF DMT not found in test stations are referred to as “absent,” “not present,” or “missing.” Taxa that rank outside the top 10 BIOREF DMT at test stations are referred to as “less abundant,” “reduced,” or “ranked lower.” The DMT found in similar abundance between the test station and BIOREF streams can be referred to as “codominant” or “in common.”

Fall

In total, nine of the BIOREF DMT were absent or much less abundant at Logtown Branch in the fall (Table 6). Three BIOREF DMT were not present, and the six remaining taxa were substantially less abundant in the fall. *Stenelmis* sp., *Maccaffertium mediopunctatum*, and *Isonychia bicolor* were absent, and *Caenis latipennis*, *C. anceps*, *Hyaella azteca*, *Tricorythodes* sp., *Cricotopus/Orthocladus* grp., and Acarina were less abundant. Only *Tanytarsus* sp. was codominant with BIOREF streams in the fall.

The DMT for the two LSFR fall samples are presented in Table 6. Overall, six of the BIOREF DMT were absent or much less abundant at LSFR #2. One DMT was absent, and five of the remaining taxa were much less abundant. *M. mediopunctatum* was absent, and *Stenelmis* sp., *C. anceps*, *H. azteca*, *I. bicolor*, and *Cricotopus/Orthocladus* grp. were comparatively reduced. *C. latipennis*, *Tricorythodes* sp., *Tanytarsus* sp., and Acarina were codominant at this station. At LSFR #1, four of the 10 BIOREF DMT were absent or much less abundant (Table 6). Two of the BIOREF DMT were absent and two were much less abundant. *C. anceps* and *M. mediopunctatum* were absent, and *H. azteca* and *I. bicolor* were less abundant. *Stenelmis* sp., *C. latipennis*, *Tricorythodes* sp., *Tanytarsus* sp., *Cricotopus/Orthocladus* and Acarina were codominant.

Presence and absence of DMT was examined among LSFR stations for fall (Table 6). Four taxa were absent or less abundant than BIOREF DMT at both stations; these included *C. anceps*, *H. azteca*, *M. mediopunctatum*, and *I. bicolor*. Of those, one taxon was absent at both stations, one ranked low upstream and was missing downstream, and two ranked low at both stations. The two remaining DMT ranked low upstream, but were found in common with BIOREF DMT at LSFR #1 downstream. The four remaining taxa were present in similar relative abundance to BIOREF DMT at both stations.

The DMT for the two Shays Creek fall samples are shown in Table 6. Five BIOREF DMT were absent and two were much less abundant at Shays Creek #2. *C. anceps*, *H. azteca*, *Tricorythodes* sp., *M. mediopunctatum*, and *I. bicolor* were absent, and *Cricotopus/Orthocladus* grp. and

Acarina were much less abundant. Three remaining DMT were found in common with BIOREF streams. *Stenelmis* sp., *C. latipennis*, and *Tanytarsus* sp. were among the DMT at both Shays Creek stations and BIOREF samples. At Shays Creek #1, seven of the BIOREF DMT were absent or much less abundant in the fall. Four BIOREF DMT were absent and three taxa were observed in much lower abundance. *H. azteca*, *M. mediopunctatum*, *I. bicolor*, and Acarina were absent, and *C. anceps*, *Tricorythodes*, and *Cricotopus/Orthocladius* were much less prevalent. *Stenelmis* sp., *C. latipennis*, and *Tanytarsus* sp. were present in similar relative abundance to BIOREF DMT at both stations.

All DMT reacted similarly between Shays Creek stations in fall (Table 6). Seven DMT were negatively affected at both stations in fall. Three BIOREF DMT were missing from both stations, two were missing upstream and ranked low downstream, one was ranked low upstream and downstream, and one ranked low upstream and was absent downstream. Only three taxa were found in common with BIOREF streams at both stations.

Table 6
 Dominant Macroinvertebrate Taxa Percentage (and Rank) for BIOREF and
 Logtown Branch, Little St. Francis River (LSFR), and Shays Creek Stations, Fall 2015

Dominant Taxa	BIOREF	LSFR#2	Logtown Branch	LSFR #1	Shays Creek #2	Shays Creek #1
<i>Stenelmis</i> sp.	7.27 (1)	1.46 (14)	--	3.49 (5)	4.66 (4)	5.09 (5)
<i>Caenis latipennis</i>	6.82 (2)	2.70 (10)	0.49 (34)	4.87 (3)	3.43 (7)	3.78 (6)
<i>Caenis anceps</i>	6.44 (3)	0.46 (43)	0.08 (84)	--	--	0.85 (24)
<i>Hyalella azteca</i>	5.96 (4)	1.62 (13)	0.49 (35)	1.62 (15)	--	--
<i>Tricorythodes</i> sp.	4.79 (5)	7.94 (3)	0.16 (61)	21.02 (1)	--	0.08 (67)
<i>Maccaffertium mediopunctatum</i>	3.68 (6)	--	--	--	--	--
<i>Tanytarsus</i> sp.	3.66 (7)	16.33 (1)	7.29 (1)	14.53 (2)	2.29 (10)	14.81 (1)
<i>Isonychia bicolor</i>	3.40 (8)	1.39 (15)	--	0.89 (25)	--	--
<i>Cricotopus/Orthocladius</i>	2.82 (9)	1.23 (18)	0.49 (36)	1.95 (10)	0.08 (58)	0.23 (49)
Acarina	2.38 (11)*	5.16 (4)	0.16 (62)	1.87 (11)*	0.82 (26)	--

Rank = numerical position of dominance in that station; -- = absent from sample; **Bold** = Notable percentage or rank. *Heptageniidae (ranked 10 in BIOREF) was omitted as DMT because it is not exclusive of others on the list; Acarina (ranked 11) was included in its place.

Spring

Overall, nine of the BIOREF DMT were not substantial components of the community at Logtown Branch in spring (Table 7). Five of the top 10 BIOREF DMT were absent, and four taxa were found in much lower abundance. *C. latipennis*, *C. anceps*, *H. azteca*, *Acentrella* sp., and *Polypedilum flavum* were absent, and *Stenelmis* sp., *Tanytarsus* sp., *Stenonema femoratum*, and *Thienemannimyia* grp. were less abundant than BIOREF streams. *Cricotopus/Orthocladius* grp. was the only DMT in common with BIOREF at Logtown Branch in the spring.

The DMT for the two LSFR spring samples are presented in Table 7. All 10 BIOREF DMT were present in the LSFR #2 spring sample; however, four of the 10 were much less abundant. *C. anceps*, *S. femoratum*, *Acentrella* sp., and *P. flavum* were much less abundant. *Cricotopus/Orthocladius* grp., *C. latipennis*, *Stenelmis* sp., *Tanytarsus* sp., *H. azteca*, and *Thienemannimyia* grp. were codominant taxa. At LSFR #1, one BIOREF DMT was absent and five were substantially reduced. *Acentrella* sp. was absent, and *C. anceps*, *S. femoratum*, *H. azteca*, *P. flavum*, and *Thienemannimyia* grp. were much less abundant. *Cricotopus/Orthocladius* grp., *C. latipennis*, *Stenelmis* sp., and *Tanytarsus* sp. were codominant DMT with BIOREF samples.

Presence and absence of DMT among LSFR spring samples is shown in Table 7. Four taxa were either absent or ranked low at both stations. One taxon was ranked low upstream and was absent downstream, and three taxa were ranked low at both stations. Two were found in common upstream and ranked low downstream. Four taxa were found in similar abundance to BIOREF DMT at both stations.

The DMT for the two Shays Creek spring samples are shown in Table 7. Four BIOREF DMT were absent, and two taxa were much less abundant in the Shays Creek #2. *C. anceps*, *S. femoratum*, *H. azteca*, and *Acentrella* sp. were absent, and *C. latipennis* and *Thienemannimyia* grp. were much less abundant. *Cricotopus/Orthocladius*, *Stenelmis* sp., *Tanytarsus* sp., and *P. flavum* were codominant with BIOREF streams. Three BIOREF DMT were absent from the Shays Creek #1 and two were much lower in abundance in spring. *C. anceps*, *S. femoratum*, and *H. azteca* were absent, and *Acentrella* sp., and *P. flavum* were less abundant. *Cricotopus/Orthocladius*, *C. latipennis*, *Stenelmis* sp., *Tanytarsus* sp., and *Thienemannimyia* grp. were codominant.

The DMT presence and absence among Shays Creek spring samples is shown in Table 7. Four taxa were absent or ranked low at both stations. Three were missing from both stations, and one was absent upstream and ranked low downstream. Two DMT were ranked low upstream and were in common to BIOREF streams downstream, and one was in common upstream and ranked low downstream. The three remaining taxa were similar in abundance to BIOREF DMT at both stations.

Table 7
 Dominant Macroinvertebrate Taxa Percentage (and Rank) for BIOREF and
 Logtown Branch, Little St. Francis River (LSFR), and Shays Creek Stations, Spring 2016

Dominant Taxa	BIOREF	LSFR#2	Logtown Branch	LSFR #1	Shays Creek #2	Shays Creek #1
<i>Cricotopus/Orthocladius</i>	8.72 (1)	14.19 (2)	33.18 (1)	11.42 (2)	20.02 (1)	8.82 (3)
<i>Caenis latipennis</i>	6.98 (2)	6.73 (3)	--	9.83 (3)	1.53 (14)	3.78 (9)
<i>Stenelmis</i> sp.	4.69 (3)	2.59 (7)	0.07 (61)	6.17 (4)	4.13 (6)	2.44 (10)
<i>Tanytarsus</i> sp.	4.37 (4)	16.04 (1)	0.52 (23)	19.25 (1)	11.54 (2)	12.91 (1)
<i>Caenis anceps</i>	3.35 (5)	0.30 (48)	--	0.75 (25)	--	--
<i>Stenonema femoratum</i>	3.09 (6)	0.52 (36)	0.15 (46)	0.83 (23)	--	--
<i>Hyalella azteca</i>	2.94 (7)	1.85 (10)	--	0.33 (46)	--	--
<i>Acentrella</i> sp.	2.35 (8)	1.11 (20)	--	--	--	0.08 (60)
<i>Polypedilum flavum</i>	2.32 (9)	0.44 (40)	--	0.42 (40)	1.76 (10)	0.39 (36)
<i>Thienemannimyia</i> grp.	2.28 (10)	2.07 (9)	0.82 (16)	0.92 (22)	3.90 (97)	4.57 (8)

Rank = numerical position of dominance in that station; -- = absent from sample; **Bold** = Notable percentage or rank.

3.2.3.2 EPT Taxa

Ephemeroptera, Plecoptera, and Trichoptera taxa richness is listed by station and BIOREF streams. Results are grouped by season and taxonomic order.

Fall

The number of Ephemeroptera (mayflies) and Heptageniidae (flathead mayflies) taxa was compiled for all stations and BIOREF streams in the fall. BIOREF streams contained 28 Ephemeroptera and eight Heptageniidae in fall samples. Logtown Branch had eight Ephemeroptera and one Heptageniidae (*S. femoratum*). LSFR station #2 had 14 Ephemeroptera and four Heptageniidae; LSFR station #1 had 16 Ephemeroptera and four Heptageniidae. Shays Creek #2 had four Ephemeroptera and no Heptageniidae, and Shays Creek #1 contained 10 and three, respectively.

BIOREF streams had five Plecoptera (stonefly) taxa. By comparison, Logtown Branch, LSFR #2, and both Shays Creek stations had no stonefly taxa. LSFR #1 had a single stonefly taxon (*Acroneuria* sp.).

There were 21 Trichoptera (caddisfly) taxa observed among fall BIOREF samples. Logtown Branch had eight, LSFR #2 had seven, and LSFR #1 had five taxa. Shays Creek #2 contained five, and Shays Creek #1 supported seven caddisfly taxa.

Spring

BIOREF spring samples had 36 Ephemeroptera and eight Heptageniidae. Logtown Branch had six Ephemeroptera and one Heptageniidae. LSFR station #2 had 15 Ephemeroptera and two Heptageniidae, and LSFR #1 also had 15 Ephemeroptera but four heptageniids. Shays Creek #2 had three Ephemeroptera and no Heptageniidae, and Shays Creek #1 increased to six and two, respectively.

BIOREF streams had 16 Plecoptera taxa. Logtown Branch supported six, LSFR #2 had nine, and LSFR #1 contained six stonefly taxa. Shays Creek #2 had two stonefly taxa, while three were observed in Shays Creek #1 samples.

Spring BIOREF samples had 26 Trichoptera taxa. Logtown Branch had nine, LSFR #2 had 11, and 10 caddisfly taxa were found in LSFR #1. Shays Creek #2 and Shays Creek #1 had 11 and nine Trichoptera taxa, respectively.

3.2.4 General Water Quality Analyses

Physicochemical water quality constituents were examined for Fredericktown area streams in the fall of 2014 and spring of 2015 (Tables 8 and 9). Constituents were compared to Missouri WQS (MoDNR 2012b), EPA suggested guidelines (EPA 2000), and results were examined for trends among stations. The EPA *Aggregate Nutrient Ecoregion XI, level III ecoregion 39* criteria used for comparison were: nitrate+nitrite as N >0.239 mg/L; Turbidity >1.425 NTU; total nitrogen >0.379 mg/L; and total phosphorus >0.006625 mg/L. Results are grouped by season and station.

3.2.4.1 Nutrients

All fall 2015 and spring 2016 water physicochemical results in Fredericktown area streams were within WQS thresholds (MoDNR 2012b) at all stations (Table 8). However, nutrient constituents exceeded EPA suggested guidelines (EPA 2000) at several stations in the fall and spring.

Fall

None of the Logtown Branch nutrient constituents exceeded EPA guidelines; however, several did exceed guidelines at LSFR stations (Table 8). Turbidity at LSFR #2 (5.2 NTU) and LSFR #1 (6.0 NTU) exceeded the EPA suggested guideline (>1.425 NTU). Total phosphorus at LSFR #2 (0.023 mg/L) and LSFR #1 (0.022 mg/L) exceeded the EPA threshold (>0.006625 mg/L). Total nitrogen and ammonia as N were below threshold concentrations at both LSFR stations. Ammonia as N was below detectable concentrations at Logtown Branch in the fall. Most nutrient constituents were relatively similar from upstream to downstream at LSFR stations in the fall.

Nutrients and other constituents exceeded EPA suggested guidelines in Shays Creek fall samples (Table 8). Turbidity at Shays Creek #2 (1.8 NTU) and Shays Creek #1 (3.8 NTU) exceeded the EPA threshold (>1.425 NTU). Total phosphorus at Shays Creek #2 (0.021 mg/L) and Shays Creek #1 (0.053 mg/L) exceeded EPA suggested guidelines (>0.006625 mg/L). Shays Creek #1 total nitrogen (1.00 mg/L) and nitrate+nitrite as N (0.32 mg/L) also exceeded EPA suggested guidelines (>0.379 mg/L and >0.239 mg/L, respectively). The downstream Shays Creek station had higher ammonia-N and chloride concentrations than the upstream station in the fall.

Spring

All physicochemical water results in Fredericktown area streams were within WQS limits (MoDNR 2012b) in the spring (Table 9). However, several nutrients and other constituents were elevated relative to EPA suggested guidelines at several stations.

Logtown Branch #1 had slightly higher turbidity (2.6 NTU) compared to the EPA threshold (1.425 NTU) in the spring (Table 9). LSFR #2 and LSFR #1 exceeded EPA suggested guidelines for turbidity (4.1 and 5.2 NTU, respectively), total nitrogen (0.37 and 0.37 mg/L, respectively), and total phosphorus (0.014 and 0.018 mg/L, respectively). Nutrient parameters were relatively similar among LSFR spring samples. Ammonia as N was below detectable concentrations at Logtown Branch and both LSFR stations in the spring.

Turbidity at Shays Creek #2 (4.1 NTU) and Shays Creek #1 (4.8 NTU) exceeded EPA guidelines. Total phosphorus at Shays Creek #2 (0.018 mg/L) and Shays Creek #1 (0.025 mg/L) also exceeded EPA guidelines. Additionally, Shays Creek #1 total nitrogen (0.69 mg/L) and nitrate+nitrite as N (0.48 mg/L) exceeded their respective suggested guidelines. Additionally, chloride increased from upstream to downstream in the spring.

3.2.4.2 Sulfate

Sulfate concentrations did not exceed Missouri WQS (MDNR 2012b) and EPA (2000) has no guidance for sulfate. However, sulfate was present and concentrations followed similar trends among associated stations in each season.

Fall

The sulfate concentration at Logtown Branch (26.9 mg/L) was nearly 3-fold higher than LSFR #2 (9.35 mg/L) and LSFR #1 (10.9 mg/L) in the fall (Table 8). The concentration increased approximately 15 percent from LSFR #2 to downstream LSFR #1. Sulfate in Shays Creek #2 (35.1 mg/L) was slightly higher than Shays Creek #1 (28.6 mg/L). Sulfate concentrations decreased roughly 20 percent from the upstream to downstream in Shays Creek.

Table 8
 Physicochemical Water Parameters for Logtown Branch,
 Little St. Francis River (LSFR), and Shays Creek Stations, Fall 2015

Station	LSFR #2	Logtown Branch #1	LSFR #1	Shays Creek #2	Shays Creek #1
Sample No.	153620	153619	153615	153616	153617
pH (Units)	7.12	7.02	6.96	8.1	8.0
Temperature (°C)	17.5	15.0	16.9	21.2	21.4
Conductivity (µS/cm)	273	255	315	399	383
Dissolved O ₂	7.27	8.03	7.00	9.26	8.17
Discharge (cfs)	0.40	0.01	0.64	0.33	0.20
NFR	5.00	<5	5.00	8.00	6.00
Turbidity (NTUs)	5.2	1.4	6.0	1.8	3.8
Total Nitrogen	0.29	0.081 ₀₅	0.26	0.36	1.00
Nitrate+Nitrite as N	0.088	<0.008	0.067	0.074	0.32
Ammonia-N	0.046 ₀₅	<0.03	0.062	<0.03	0.13
Sulfate	9.35	26.9	10.9	35.1	28.6
Chloride	7.86	6.51	7.86	1.83 ₀₅	4.59 ₀₅
Total Phosphorus	0.023 ₀₅	<0.01	0.022 ₀₅	0.021 ₀₅	0.053

Units mg/L unless otherwise labeled; **Highlighted** = Notable; *Italics* = exceeding EPA (2000) suggested guidelines used for comparison: NO₃+NO₂-N >0.239 mg/L; Turbidity >1.425 NTU; TN >0.379 mg/L; TP >0.006625 mg/L. Subscript qualifiers: #05 = estimated value, detected below the Practical Quantitation Limit (PQL). “Less than” values were below laboratory detection limits.

Spring

The sulfate concentration at Logtown Branch (31.2 mg/L) was approximately 2-times higher than LSFR #2 (13.7 mg/L) and LSFR #1 (14.6 mg/L) in the spring (Table 9). The sulfate concentration increased 6 percent from upstream LSFR #2 to downstream LSFR #1. Sulfate was substantially higher in Shays Creek #2 (63.0 mg/L) than Shays Creek #1 (37.9 mg/L) in the spring. There was a relative decrease in sulfate concentrations of approximately 50 percent from upstream to downstream in Shays Creek.

3.3 Surface Water: Dissolved Metals

Surface water was analyzed for dissolved metals at all stations in both seasons (Tables 10 and 11). Notable results are those concentrations that exceed individual hardness dependent WQS (MoDNR 2014) or concentrations that were elevated among stations. All dissolved metals were well below Missouri WQSs (MoDNR 2014) in both seasons, so trends among Logtown Branch and LSFR stations, as well as within Shays Creek will be highlighted. Results are grouped by season and station.

Table 9
 Surface Water Physicochemical Parameters for Logtown Branch,
 Little St. Francis River (LSFR), and Shays Creek Stations, Spring 2016

Station/ Sample No.	LSFR #2 161830	Logtown Branch #1 161832	LSFR #1 161828	Shays Creek #2 161820	Shays Creek #1 161822
pH (Units)	7.22	7.02	7.44	7.67	8.01
Temperature (°C)	13.8	10.2	13.6	15.9	17.6
Conductivity (µS/cm)	222	261	221	297	320
Dissolved O ₂	9.73	10.15	8.88	9.97	11.32
Discharge (cfs)	35.54	0.58	45.68	1.49	3.06
NFR	<5 ₀₆	<5 ₀₆	5 ₀₆	<5 ₀₆	<5 ₀₆
Turbidity (NTUs)	4.1	2.6	5.2	4.1	4.8
Total Nitrogen	0.37	0.073 ₀₅	0.37	0.27	0.69
Nitrate+Nitrite as N	0.22	<0.008	0.22	0.045	0.48
Ammonia-N	<0.03	<0.03	<0.03	<0.03	<0.03
Sulfate	13.7	31.2	14.6	63.0	37.9
Chloride	6.03	8.30	5.96	3.10 ₀₅	6.22
Total Phosphorus	0.014 ₀₅	<0.01	0.018 ₀₅	0.018 ₀₅	0.025 ₀₅

Units mg/L unless otherwise labeled; **Highlighted** = Notable; *Italics* = exceeding EPA (2000) suggested guidelines used for comparison: NO₃+NO₂-N >0.239 mg/L; Turbidity >1.425 NTU; TN >0.379 mg/L; TP >0.006625 mg/L. Subscript qualifiers: #05 = estimated value, detected below the Practical Quantitation Limit (PQL); #06 = estimated value, QC data outside limits. “Less than” values were below laboratory detection limits.

Fall

Several dissolved metals were notable in the Logtown Branch #1/LSFR association in fall samples (Table 10). Arsenic was not detected in Logtown Branch, but it was present in low concentrations at LSFR #2 (0.60 µg/L) and LSFR #1 (0.60 µg/L). Dissolved copper in Logtown Branch #1 (1.50 µg/L) was higher than LSFR #2 (0.53 µg/L) and LSFR #1 (0.59 µg/L). Dissolved lead was not detected at Logtown Branch or LSFR stations. Dissolved nickel at Logtown Branch (2.81 µg/L) was higher than LSFR #2 (0.51 µg/L) and LSFR #1 (0.74 µg/L). Zinc was present at all stations including LSFR #2 (1.07 µg/L) and LSFR #1 (1.03 µg/L), but the Logtown Branch (0.98 µg/L) had a slightly lower zinc concentration.

Several dissolved metals were notable in Shays Creek fall samples (Table 10). Arsenic was present in Shays Creek #2 (2.73 µg/L) and Shays Creek #1 (1.96 µg/L). Copper was present at Shays Creek #2 (1.38 µg/L) and #1 (0.95 µg/L). Dissolved lead was observed at Shays Creek #2 (1.45 µg/L) and #1 (1.54 µg/L), which was below WQS chronic toxicity level (6.15 µg/L at 230 mg/L as CaCO₃). Nickel was observed at Shays Creek #2 (6.50 µg/L) and #1 (3.59 µg/L). Zinc was present in slightly higher concentrations upstream (1.76 µg/L) than downstream (1.15 µg/L).

Table 10
 Dissolved Metals and Hardness as CaCO₃ in Surface Water (Grab Sample)
 in Logtown Branch, Little St. Francis River (LSFR), and Shays Creek Stations, Fall 2015

Station/ Sample No.	LSFR #2 153620	Logtown Branch #1 153619	LSFR #1 153615	Shays Creek #2 153616	Shays Creek #1 153617
Arsenic	0.60 ₀₅	<0.50	0.60 ₀₅	2.73	1.96
Barium	86.7	89.0	84.6	78.2	139
Cadmium	<0.10	<0.10	<0.10	<0.10	<0.10
Cobalt	<1	<1	<1	<1	<1
Copper	0.53 ₀₅	1.50	0.59 ₀₅	1.38	0.95 ₀₅
Iron	42.0	3.45 ₀₅	44.6	25.2	35.0
Lead	<0.50	<0.50	<0.50	1.45	1.54
Manganese	104	2.96	105	90.1	114
Nickel	0.51 ₀₅	2.81	0.74 ₀₅	6.50	3.59
Silver	<0.50	<0.50	<0.50	<0.50	<0.50
Zinc	1.07	0.98 ₀₅	1.03	1.76	1.15
Calcium (mg/L)	29.8	44.9	30.4	50.7	46.6
Magnesium (mg/L)	19.0	23.8	19.2	27.4	26.0
Dissolved Hardness (mg/L)	153	210	155	239	223

Units µg/L unless noted otherwise; **Bold** = outside WQS acceptable range, a = acute, c = chronic toxicity (MDNR 2014); note that there are no WQS acute or chronic exceedances in this table; “Less than” values were below laboratory detection limits; **Highlighted** = notable or trend; Qualifiers - #₀₅=Estimated value, detected below Practical Quantitation Limits (PQL).

Spring

Three dissolved metals were notable in Logtown Branch and LSFR spring samples (Table 11). Arsenic was not detected in Logtown Branch or LSFR in the spring. Dissolved copper in Logtown Branch (1.20 µg/L) was higher than LSFR #2 (0.58 µg/L) and LSFR #1 (0.56 µg/L). Dissolved lead was not detected in Logtown Branch or LSFR stations. Logtown Branch dissolved nickel (3.04 µg/L) was elevated compared to LSFR #2 (0.99 µg/L) and LSFR #1 (1.08 µg/L). Dissolved zinc was detected in Logtown Branch (0.56 µg/L), but it was not detected in either LSFR station in the spring.

All dissolved metals were below hardness dependent WQS (MoDNR 2014) in Shays Creek spring samples (Table 11). Arsenic was present at Shays Creek #2 (1.77 µg/L) and #1 (0.84 µg/L). Cobalt was observed at Shays Creek #2 (2.56 µg/L), but it was not detected in #1. Copper was present at Shays Creek #2 (2.93 µg/L) and #1 (1.62 µg/L). Dissolved lead was observed at Shays Creek #2 (0.88 µg/L) and #1 (0.71 µg/L) in concentrations below WQS chronic toxicity level (5.31 µg/L at 200 mg/L as CaCO₃). The dissolved nickel concentration was much higher at Shays Creek #2 (29.6 µg/L) compared to Shays Creek #1 (7.37 µg/L). Zinc was observed in similar concentrations at Shays Creek #2 (0.84 µg/L) and #1 (0.91 µg/L).

Table 11
 Dissolved Metals and Hardness as CaCO₃ in Surface Water (Grab Sample)
 in Logtown Branch, Little St. Francis River (LSFR), and Shays Creek Stations, Spring 2016

Station/ Sample No.	LSFR #2 161830	Logtown Branch #1 161832	LSFR #1 161828	Shays Creek #2 161820	Shays Creek #1 161822
Arsenic	<0.50	<0.50	<0.50	1.77	0.84 ₀₅
Barium	50.8	46.7	50.1	38.1	55.2
Cadmium	<0.10	<0.10	<0.10	<0.10	<0.10
Cobalt	<1	<1	<1	2.56 ₀₅	<1
Copper	0.58 ₀₅	1.20	0.56 ₀₅	2.93	1.62
Iron	53.2	21.8	56.8	13.7	34.6
Lead	<0.50	<0.50	<0.50	0.88 ₀₅	0.71 ₀₅
Manganese	54.5	4.09	57.2	53.2	48.2
Nickel	0.99 ₀₅	3.04	1.08	29.6	7.37
Silver	<0.50	<0.50	<0.50	<0.50	<0.50
Zinc	<0.50	0.56 ₀₅	<0.50	0.84 ₀₅	0.91 ₀₅
Calcium (mg/L)	20.5	27.5	22.0	43.8	36.8
Magnesium (mg/L)	12.6	14.8	13.4	22.9	19.7
Dissolved Hardness (mg/L)	103	130	110	204	173

Units µg/L unless noted otherwise; **Bold** = outside WQS acceptable range, a = acute, c = chronic toxicity (MDNR 2014); note that there are no WQS acute or chronic exceedances in this table; “Less than” values were below laboratory detection limits; **Highlighted** = notable or trend; Qualifiers - #₀₅=Estimated value, detected below Practical Quantitation Limits (PQL).

3.4 Fine Sediment: Total Metals Characterization

Benthic fine sediment (<2.0 mm) was characterized for total arsenic, cadmium, copper, lead, nickel, silver, and zinc concentrations at the Fredericktown area streams in fall 2015 samples (Table 12). Notable results (Table 12; Figures 3-6) are those that exceeded or were near threshold concentrations for individual metals (PEC and PEQ), as identified by MacDonald et al. (2000), or those that exceeded Tri-state Mining District (TSMD) site specific criteria (T₁₀; MacDonald et al. 2009) for the mixture or combination of metals ($\sum$ PEQ_{Cd, Pb, Zn} and mean PEQ_{metals}).

Total metals concentrations in benthic fine sediment were analyzed for the Fredericktown area streams in fall 2015 (Table 12). Four metals were present in concentrations above or near PEC thresholds (MacDonald et al. 2000; 2009). Arsenic, lead, and nickel exceeded PEC thresholds, and copper was near its PEC (Figures 3-6). The fine sediment of Logtown Branch and both Shays Branch stations had potentially toxic concentrations of several metals, whereas both LSFR stations were well below PEC thresholds.

At Logtown Branch #1, fine sediment lead and nickel concentrations exceeded PECs, and copper was near its threshold in the fall 2015 sample (Table 12; Figures 4-6). Lead (533 mg/kg) exceeded the PEC (128.0 mg/kg) and was over 4 times higher than the PEQ. Nickel (69.9 mg/kg) exceeded the PEC (48.6 mg/kg) and was approximately 1.4 times the individual PEQ. Copper (122.0 mg/kg) was near the PEC (149 mg/kg). The measure combining cadmium, lead, and zinc ($\sum \text{PEQ}_{\text{Cd, Pb, Zn}} = 4.318$) did not exceed the threshold ($T_{10} > 7.92$), but the mean $\text{PEQ}_{\text{metals}}$ (1.023) nearly reached the threshold (mean $\text{PEQ}_{\text{metals}} > 1.11$) for all metals combined. The individual lead concentration at Logtown Branch (533.0 mg/kg) also exceeded the TSMD site-specific criterion ($T_{10} = 150$ mg/kg).

Total metals concentrations associated with benthic fine sediments did not exceed individual PECs for either LSFR station in fall 2015 (Table 12; Figures 3-6). However, total recoverable concentrations for arsenic, copper, lead, and nickel increased from upstream LSFR #2 to downstream LSFR #1 of Logtown Branch. From upstream LSFR #2 to downstream LSFR #1, arsenic increased from <1.25 mg/kg to 1.550 mg/kg, copper increased from 1.440 mg/kg to 3.26 mg/kg, lead increased from 8.1 mg/kg to 30.4 mg/kg, and nickel increased from 3.9 mg/kg to 6.83 mg/kg. Cadmium was detected at LSFR #2 (0.133 mg/kg) but not at LSFR #1 (<0.100 mg/kg). Silver and zinc showed no obvious increase from stations upstream versus downstream of Logtown Branch. The individual lead concentrations at LSFR stations did not exceed the TSMD site-specific criterion ($T_{10} = 150$ mg/kg).

At Shays Creek #2, total arsenic, lead, and nickel concentrations exceeded PECs in the fall 2015 sample (Table 12; Figures 3, 5, and 6). Arsenic (89.9 mg/kg) was over 2.6-times its PEC threshold (33.9 mg/kg). Lead (495.0 mg/kg) exceeded its threshold (128.0 mg/kg) by 3.8-times, and nickel (101.0 mg/kg) exceeded its individual PEC threshold (48.6 mg/kg) by 2.1-times. The measure combining cadmium, lead, and zinc ($\sum \text{PEQ}_{\text{Cd, Pb, Zn}} = 4.318$) did not exceed the threshold ($T_{10} > 7.92$), but the mean $\text{PEQ}_{\text{metals}}$ (1.346) exceeded the threshold (mean $\text{PEQ}_{\text{metals}} = 1.11$) for all metals combined. The individual lead concentration at Shays Creek #2 (495.0 mg/kg) also exceeded the TSMD site-specific criterion ($T_{10} = 150$ mg/kg).

Shays Creek #1 total arsenic exceeded the PEC in the fall of 2015, and two other metals were slightly elevated (Table 12; Figures 3, 5, and 6). Arsenic (37.0 mg/kg) was 1.1-times higher than the PEC threshold (33.9 mg/kg). The lead concentration (108.0 mg/kg) was slightly lower than the PEC threshold (128.0 mg/kg). Nickel (22.4 mg/kg) was approximately half of the PEC threshold (48.6 mg/kg). The measure combining cadmium, lead, and zinc ($\sum \text{PEQ}_{\text{Cd, Pb, Zn}} = 1.021$) did not exceed the threshold ($T_{10} > 7.92$), and the mean $\text{PEQ}_{\text{metals}}$ (0.378) did not exceed the threshold (mean $\text{PEQ}_{\text{metals}} = 1.11$) for all metals combined. The individual lead concentration at Shays Creek #1 (108.0 mg/kg) did not exceed the TSMD site-specific criterion ($T_{10} = 150$ mg/kg).

Concentrations of all fine sediment metals analyzed for this study decreased from upstream to downstream in Shays Creek (Table 12). Arsenic decreased from Shays Creek #2 (89.9 mg/kg) to Shays Creek #1 (37.0 mg/kg), both of which were above the PEC. Cadmium decreased from Shays Creek #2 (1.73 mg/kg) to Shays Creek #1 (0.627 mg/kg), and copper decreased from

upstream (24.6 mg/kg) to downstream (11.1 mg/kg). Neither cadmium nor copper exceeded their respective PECs. The lead concentration at Shays Creek #2 (495.0 mg/kg) was above the PEC, but it was slightly below the PEC at Shays Creek #1 (108.0 mg/kg). Nickel decreased from above the PEC at Shays Creek #2 (101.0 mg/kg) to well below the PEC at Shays Creek #1 (22.4 mg/kg). Silver decreased from upstream (0.459 mg/kg) to downstream (<0.250 mg/kg), and zinc also decreased from Shays Creek #2 (47.9 mg/kg) to Shays Creek #1 (23.3 mg/kg).

Table 12
 Fine Sediment Character: Total Recoverable Metals Concentrations (mg/kg)
 for Logtown Branch, Little St. Francis River (LSFR), and Shays Creek Stations, Fall 2015

Station Sample No.	LSFR#2 153562	Logtown Br. #1 153561	LSFR#1 153557	Shays Cr. #2 153558	Shays Cr. #1 153559	PEC Threshold	PEQ Threshold
Arsenic (PEQ)	<1.25 (N/A)	14.7 ₀₉ (0.434)	1.550 ₀₅ (0.046)	89.9 (2.652)	37.0 (1.091)	33.9	>1.0
Cadmium (PEQ)	0.133 _{05,11} (0.027)	0.702 ₁₁ (0.141)	<0.100 (N/A)	1.73 ₁₁ (0.347)	0.627 ₁₁ (0.126)	4.98	>1.0
Copper (PEQ)	1.440 (0.010)	122.0 (0.819)	3.26 (0.022)	24.6 (0.165)	11.1 (0.074)	149	>1.0
Lead (PEQ)	8.100 (0.063)	533.0 ₀₉ (4.164)	30.4 (0.237)	495.0 ₀₉ (3.867)	108.0 (0.844)	128.0	>1.0
Nickel (PEQ)	3.900 (0.080)	69.9 (1.438)	6.83 (0.141)	101.0 ₀₉ (2.078)	22.4 (0.461)	48.6	>1.0
Silver (PEQ)	<0.250 (N/A)	0.273 ₀₅ (0.124)	<0.250 (N/A)	0.459 ₀₅ 0.209	<0.250 (N/A)	2.2*	>1.0
Zinc (PEQ)	8.140 (0.018)	18.1 (0.039)	8.12 (0.018)	47.9 ₀₉ (0.104)	23.3 (0.051)	459.0	>1.0
ΣPEQ _{Cd,Pb,Zn (only)}	0.108	4.344	0.255	4.318	1.021	--	≥7.92
Mean PEQ _{metals}	0.028	1.023	0.066	1.346	0.378	--	T ₁₀ ≥1.11

Units are mg/kg; PEC=Probable Effects Concentration (MacDonald et al. 2000); **Bold**=above PEC; PEQ = Probable Effects Quotient=metal value/PEC; Mean PEQ = ΣPEQ/#metals; ΣPEQ = sum PEQs; ; T₁₀ = toxicity threshold (MacDonald et al. 2009); Qualifiers - #₀₅ = estimated value, detected below PQL, #₀₉ = sample was diluted during analysis, #₁₁ = Estimated value, matrix interference; * = MacDonald and MacFarlane (1999) in Wisconsin DNR (2003). “Less than” values were below laboratory detection limits.

Figure 3: Total Arsenic by Station

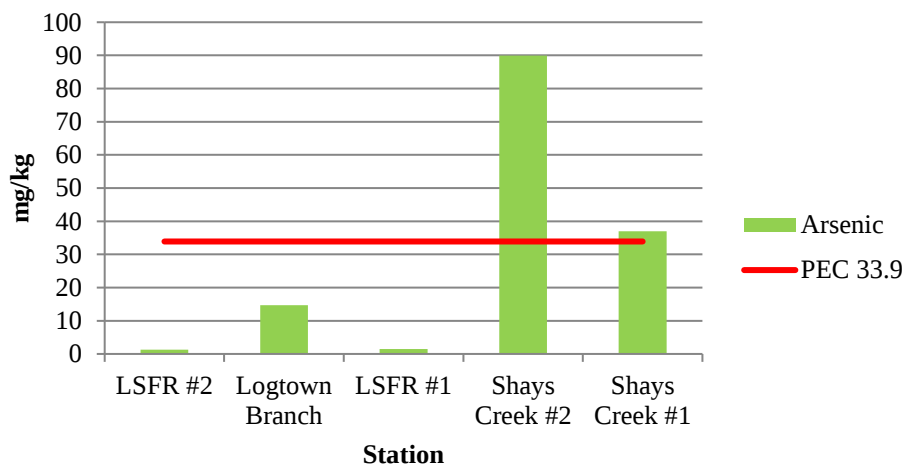


Figure 4: Total Copper by Station

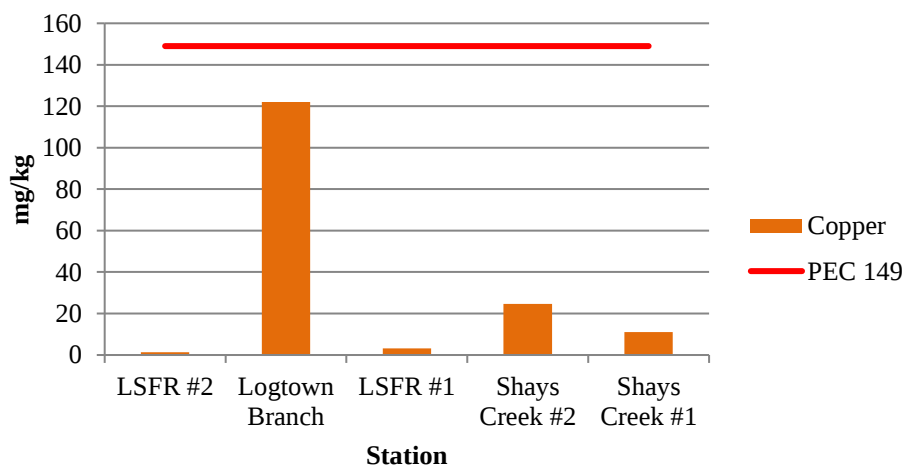


Figure 5: Total Lead by Station

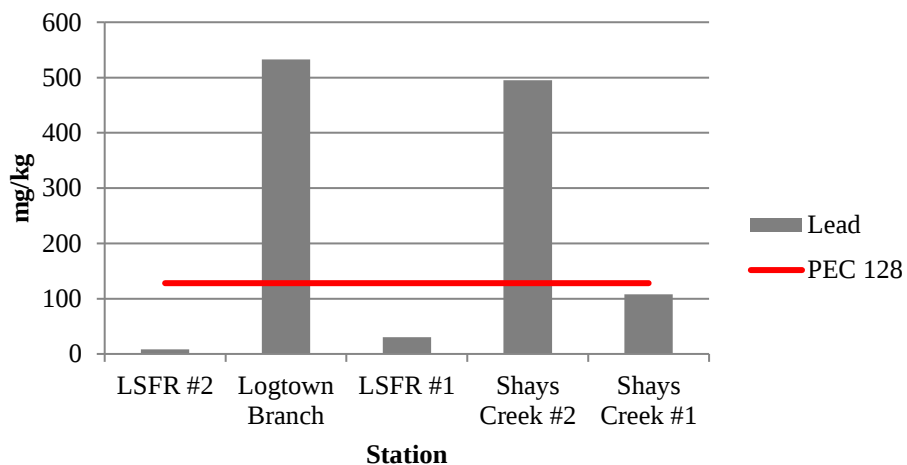
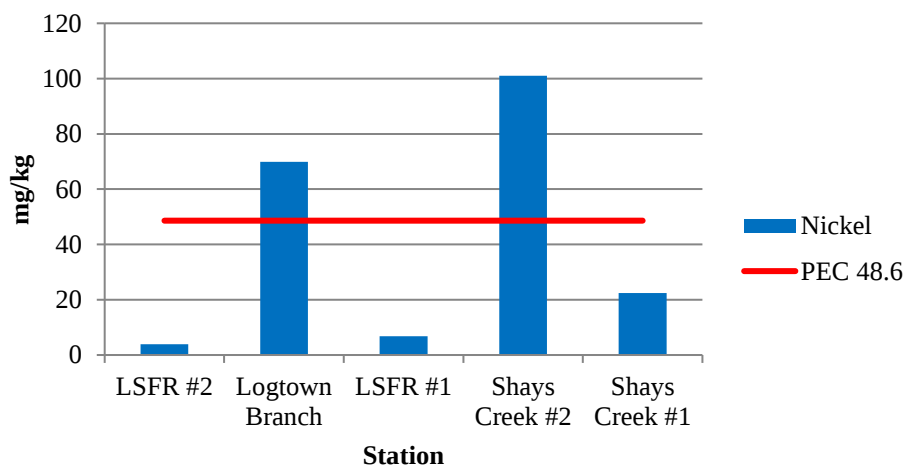


Figure 6: Total Nickel by Station



4.0 Discussion

The discussion section includes examination of the stream habitat assessment; biological assessment, which includes macroinvertebrate community assessments and general physicochemical water quality analyses; dissolved metals analyses in surface water; and total metals characterization of the benthic fine sediment. The discussion highlights, consolidates, and compares notable results with the intention of identifying effects and potential sources.

4.1 Stream Habitat Assessment

According to the SHAPP (MoDNR 2016c), stream habitat quality is considered comparable to the SHAPP control when the test stream score is ≥ 75 percent of the control score. Of the Fredericktown area stations, the stream habitat was comparable to the SHAPP control only at LSFR #1 (77 percent). LSFR #2 upstream (72 percent) and Logtown Branch (71 percent) both were slightly below the threshold. Shays Creek #2 (63 percent) and Shays Creek #1 (59 percent) were substantially lower than the SHAPP control score.

Overall, one commonly observed difference between the SHAPP control and most Fredericktown area stations was the coverage of benthic fine sediment. With the exception of the Logtown Branch station, all stations had higher percentages of fine sediment and bar development. Many of the remaining stream habitat variables measured in the test stations, and described below, can be associated with fine sediment deposition.

Logtown Branch scored lower than the control for velocity/depth regime, channel flow status, riffle quality and vegetative protection. Although the stream banks were moderately stable, they were very high (tall) for a small stream. It is apparent that the stream periodically experiences very high flow events. Past mining practices at Catherine Mine and in the remaining Logtown Branch watershed has the potential to influence the intermittently high flow and these habitat variables. Less sediment was observed in Logtown Branch compared to other stations, probably due to being washed out during high flow events.

The LSFR #2 score was near the threshold to be considered comparable to the control, but the downstream LSFR #1 was comparable to the SHAPP control. The noticeable difference was that LSFR #2 had much less suitable epifaunal substrate and a very unstable left bank compared to LSFR #1. Bank stability and less vegetative protection at both stations may have contributed to heavy sediment deposition at both stations.

Both Shays Creek stations scored well below the minimum threshold needed to be considered comparable to the SHAPP control. Although scores were generally similar between stations, they were slightly higher upstream. Scores were slightly higher upstream due to more velocity/depth regimes, greater channel flow status, and more vegetative protection. However, both stations had extremely heavy sediment deposition, less vegetative protection, and riparian vegetation compared to the control. Much of the flow upstream of Shays Creek #2 is controlled by the Slime Pond, a Mine LaMotte tailings pond now associated with a recreational-vehicle park. The watershed around both Shays Creek stations is grazed pasture with a sparsely wooded riparian corridor.

Relatively poor stream habitat quality may have contributed to the results of this study at most stations, excluding LSFR #1. Habitat limitations, such as heavy sediment deposition, was a substantial contributor to lower scores at most stations. These limitations may be a legacy from past mining practices in the area, agricultural practices, and urban influences. Habitat limitations, however, are not exclusive of other potential influences that may affect the aquatic community.

4.2 Biological Assessment

A biological assessment is a combined examination of macroinvertebrate community and physicochemical water quality, both of which are necessary to gauge the health of the stream. Macroinvertebrate community analyses include examination of primary and secondary metrics. Physicochemical water quality constituents are highlighted if notable. The discussion integrates notable results to identify areas of interest and potential influences.

4.2.1 Macroinvertebrate Community Analyses: Primary Metrics

Macroinvertebrate community analyses were conducted using primary metrics for the Fredericktown area streams. Biological metrics are a measure of the ability of a stream to support the protection of warm water aquatic life beneficial use designation (AQL). These metrics also can aid in determining outstanding contributors to scores, potentially influential sources, and whether an influence is constant or intermittent. The discussion is arranged by stream or station.

Logtown Branch and LSFR

Logtown Branch attained fully supporting status in the fall and partially supporting in the spring. Suboptimal metric values for EPTT and BI contributed to an MSCI score of 16 in the fall, whereas all four metric values contributed to the lower score in the spring. This seasonal difference may be due to an intermittent influence from within or upstream in Logtown Branch. The TR and SDI metric values were proportionally much lower than their respective threshold values in the spring than in the fall. One would expect similar or proportional increases relative to the elevated criteria if no influence affected the number of taxa or diversity in the community. It appears that an intermittent influence within or upstream in Logtown Branch may have affected the macroinvertebrate community composition.

LSFR #2 attained fully supporting MSCI scores during both seasons. Metrics values such as a low EPTT and high BI in the fall, and a high BI with low SDI in the spring contributed to the slightly lower, yet optimal scores. One metric common to both seasons was suboptimal BI, suggesting that an organic influence or disturbance may be a continuous influence on the macroinvertebrate community at this station. However, the spring BI was very close to the optimal level, which implies there was less of an organic influence during that season. Overall, influences from within or upstream of LSFR #2 were apparent, but they did not substantially affect the community composition. This station is the most upstream LSFR station and the upper bracket for Logtown Branch.

Downstream of Logtown Branch, LSFR #1 was partially supporting of the AQL beneficial use designation during both seasons. Three metrics contributed to the less than optimal MSCI scores in each season. Either the TR (fall) or EPTT (spring) were the only metric values to reach their respective optimal metric scoring ranges; however, the TR was consistently much lower than the upstream LSFR #2 samples, suggesting there was some influence at this point. Despite the lower scores, most metric values were very close to their optimal scoring ranges; a slight increase in any one of the suboptimal metric values would have changed the MSCI scores and biological support categorizations to fully supporting in both seasons. The macroinvertebrate community composition was affected by some influence within or from upstream of LSFR #1.

Incorporating the status of all Logtown Branch/LSFR stations may identify or locate potential influences affecting the quality of these streams. LSFR #2 was fully supporting in both seasons, Logtown Branch was fully supporting in the fall and partially supporting in the spring, and LSFR #1 was partially supporting in both seasons. The MSCI scores suggest some influence in the Logtown Branch watershed appears to be intermittently affecting the LSFR #1 support status. However, in the fall, the primary individual metrics (TR, EPTT, BI, and intermittently SDI) in Logtown Branch were actually farther from the optimal range than those metric values at LSFR #1, despite its higher support categorization in that season. In the spring, all of the Logtown Branch metric values were suboptimal, and the MSCI was lower than LSFR #1. Both trends in the individual metrics suggest Logtown Branch was continuously affected and may also have had some slight effect on the community at LSFR #1. Catherine Mine is located at the head of Logtown Branch. The mine and mill site was used for approximately 150 years, and it is presently used as a repository for mine related material as part of remediation efforts in the Fredericktown area.

Shays Creek

Shays Creek stations were partially supporting of the AQL beneficial use designation in both seasons. All Shays Creek metric values, with the exception of the SDI at Shays Creek #1 in the fall, were suboptimal and contributed to the partially supporting MSCI scores. The Shays Creek #2 EPTT metric value was non-supporting in the fall and the lowest among all stations in the spring. In fact, all four metric values at Shays Creek #2 were farther from their individual optimal scoring ranges than those observed downstream in Shays Creek #1. This pattern among metric values suggests that there may be an influence within or upstream of Shays Creek #2 affecting the macroinvertebrate community composition in that station and potentially the downstream station. The Slime Pond is a Mine LaMotte tailings pond with a nearby tailings pile that is located immediately upstream of Shays Creek #2. Outflow from the Slime Pond is the continuous source of water in Shays Creek. Most of the immediate watershed including both stations on Shays Creek is grazed pasture, which could also contribute to the observed biological metric scores. Suboptimal BI scores contributed to the stream's status, suggesting there may be some organic influence in the stream as well. Slightly better metric values downstream imply there may be some recovery occurring, presumably due to distance from a contributing stressor.

4.2.2 Candidate Reference Stream Comparisons: Stream Size Influence

Candidate reference stream criteria were developed to determine if stream size contributed to the macroinvertebrate community composition of the smaller streams in this project. When the small candidate reference criteria were developed, it was apparent that candidate reference streams in the Ozark/Upper St. Francis/Castor EDU contained slightly different macroinvertebrate communities than the larger wadeable/perennial BIOREF streams of the EDU. Overall, macroinvertebrate communities in small candidate reference streams had a lower taxa richness, fewer sensitive EPTT, taxa that were less tolerant to organic pollution or disturbance, and a slightly more diverse population in the fall and less diverse in the spring than BIOREF streams. These candidate reference criteria were then compared to individual metric values. Stream size is considered to be a potential contributor to the macroinvertebrate community composition if the biological support category using candidate reference criteria is different from the original support category using larger stream BIOREF criteria.

Logtown Branch and Shays Creek metric values were compared to these candidate reference criteria. The Logtown Branch metric scores, MSCI, and support category did not change in either season, which suggests that stream size did not have an obvious effect on the macroinvertebrate community composition. Shays Creek, however, had mixed results. In the fall, Shays Creek metric scores did not change, but the spring MSCI scores changed from 12 to 16 for both Shays Creek stations. The biological support category increased from partial to full support at both stations. The TR and SDI metric scores increased for each Shays Creek station because the candidate reference criteria were considerably lower than BIOREF thresholds in the spring. The similarity with smaller candidate reference stream criteria indicates that stream size may have affected the macroinvertebrate community composition and ultimately the original partial support categorizations for Shays Creek stations in the spring. Despite the intermittent similarity with candidate reference streams, metric values for sensitive taxa (EPTT and BI) remained well outside the optimal criteria range. These indicators suggest the Shays Creek communities were also affected by some influence that was not prevalent in the small candidate reference streams of the EDU. Although stream size may have affected the community composition, it may not be the single contributing factor to the status of Shays Creek stations in the spring.

4.2.3 Macroinvertebrate Community Analyses: Secondary Metrics

Two secondary metrics were used to examine trends in Fredericktown area stream communities. The DMT metric and individual EPT taxa were examined to identify differences between BIOREF streams and test stations, as well as among test stations. The number and composition of DMT and EPT may identify areas of interest.

4.2.3.1 Dominant Macroinvertebrate Taxa

The dominant macroinvertebrate taxa metric is based on the presence and abundance of taxa. DMT analysis is used to highlight similarities and differences between BIOREF streams and test stations, and among test stations themselves. A station without stressors is expected to have the same DMT in similar abundance as BIOREF samples. General and specific trends in the number of DMT per station may identify areas of interest or potential sources of effects.

Individual Station Effects – DMT

The Logtown Branch macroinvertebrate community was substantially different from the BIOREF DMT communities in both seasons. Only one taxon was codominant with BIOREF streams in each season. Nine BIOREF DMT were absent (three) or reduced (six) in the fall, and nine were absent (five) or reduced (four) in the spring. The overall number of DMT was similar between seasons, with a relative increase in the number of absent DMT in the spring; this coincided with the decreased support categorization for spring.

The DMT at LSFR stations were not similar to BIOREF stream communities, and they were slightly different from one another depending on season. Four DMT were in common with BIOREF streams at both stations in the fall and four were in common in spring, illustrating a consistent and substantial difference between LSFR stations and BIOREF streams. Generally, one was absent and five were reduced upstream, while two DMT were absent and two reduced downstream in fall. Additionally, two ranked low upstream and were in common downstream, which suggests LSFR #2 may be slightly more influenced than LSFR #1 in the fall. In spring, four were reduced upstream, while one was absent and five reduced downstream. Two of those DMT ranked low downstream and were found in common with BIOREF streams upstream. This illustrated LSFR #1 may be slightly more affected in spring.

The DMT comparison showed that both Shays Creek stations were consistently very different from BIOREF streams with slight differences among stations. Only three DMT were found in common in the fall and three in spring, illustrating a substantial difference between the Shays Creek stations and BIOREF stream communities. In general, DMT reacted similarly among Shays Creek stations in both seasons; however, there were slight differences from upstream to downstream. More DMT were either missing or ranked low upstream than the downstream station. Two DMT were absent upstream that ranked low downstream in fall. One was absent upstream that ranked low downstream, and two were ranked low upstream that were in common downstream in spring. There was also one more missing upstream than downstream in both seasons. The implication is there may be more of a consistent influence upstream affecting the macroinvertebrate community upstream, with some recovery downstream in Shays Creek.

General Area Effects – DMT

A large number of BIOREF DMT were absent or reduced in Fredericktown area streams. BIOREF DMT such as *Caenis anceps*, *Hyaella azteca*, *Maccaffertium mediopunctatum*, *Isonychia bicolor*, and *Cricotopus/Orthocladius* grp. (except LSFR #1), were commonly absent or reduced from Fredericktown area streams in the fall. In the spring, *C. anceps*, *Stenonema femoratum*, *Acentrella* sp., *H. azteca* (except LSFR #2), and *Polypedilum flavum* (except Shays Creek #2) were absent or reduced from Fredericktown area streams. Comparisons with BIOREF DMT suggest these taxa were limited in abundance due to sensitivity to an influence present in most Fredericktown area streams. It also appears the influence was continuous since a large number of DMT were affected during both seasons.

The DMT among Fredericktown area streams that were in common with DMT at BIOREF streams suggests they may be tolerant of influences. *Tanytarsus* sp. was among the DMT in common with BIOREF streams at all stations except Logtown Branch in spring. Its presence at the majority of stations in both seasons suggested that the taxon was generally tolerant of influences that affected other DMT in both seasons, with the exception of DMT at Logtown Branch. Despite its tolerance to most general influences, *Tanytarsus* sp. appears to be affected by an additional influence at Logtown Branch in spring. Interestingly, *Cricotopus/Orthocladius* grp. was not among the DMT in common with BIOREF streams in fall, except at LSFR #1, and it was a DMT at all stations in the spring. This taxa group may have been more sensitive to influences that affected most DMT stations in fall, yet very tolerant of influences that affected other DMT at all stations in the spring. Emergence is not a likely reason for their scarcity in fall, because they were among the top 10 DMT at BIOREF streams in fall and should be present.

Specific Areas of Interest – DMT Taxa

Additional DMT that were absent/reduced and present from particular stations may identify specific areas of interest. In the fall, excluding those BIOREF DMT that were absent/reduced or present in all stations, *Stenelmis* sp. (except LSFR #2), *C. latipennis*, *Tricorythodes* sp. and *Acarina* were not DMT in Logtown Branch, but these taxa were similar in abundance to BIOREF DMT in LSFR stations. This suggests the abundance of these taxa was limited by some additional influence in Logtown Branch that was not present or in either LSFR station. Similarly, *Tricorythodes* sp. and *Acarina* appeared to be negatively affected in both Shays Creek stations, as well as Logtown Branch, by a stressor in the fall that apparently did not affect the DMT in the LSFR stations.

In the spring, again excluding those BIOREF DMT that were absent/reduced or present at all stations, *C. latipennis*, *Stenelmis* sp., *Tanytarsus* sp., and *Thienemannimyia* grp. were absent/reduced DMT in Logtown Branch, but they were among DMT at both LSFR stations. The implication is that an influence was negatively affecting DMT in Logtown Branch that was not in LSFR stations. *Hyaella azteca* and *Thienemannimyia* grp. were also absent or ranked lower in Logtown Branch and LSFR #1, but were DMT upstream at LSFR #2. The additional influence present suggested from Logtown Branch may have influenced the DMT at LSFR #1 immediately downstream. Similarly, *C. latipennis* was apparently inhibited at Shays Creek #2 and Logtown Branch and not LSFR stations, potentially suggesting an additional and similar influence at the two stations. *Thienemannimyia* grp. was affected at Shays Creek #2, Logtown Branch, and LSFR #1, but not at LSFR #2 upstream, implying the influence may also be affecting DMT in LSFR downstream as well in spring. Only the most commonly absent or reduced taxa were affected at Shays Creek #1, which suggests the presence of a general area-wide influence at that station. Together Logtown Branch, Shays Creek #2, and (to an extent) LSFR #1, the downstream bracket to Logtown Branch, appear to be affected by an additional influence on the DMT beyond the general influence present at all stations.

Overall, the DMT examination illustrated that all Fredericktown area stream macroinvertebrate communities were not similar to BIOREF stream communities, some more so than others. Logtown Branch and Shays Creek #2 DMT appeared to be affected by an additional influence (or multiple influences) that was (or were) not prevalent in the other Fredericktown area streams. Downstream LSFR #1 DMT were also affected in spring by an influence that was not apparent upstream in LSFR #2. Shays Creek #1 DMT indicated the DMT were not as influenced as upstream Shays Creek #2 in spring.

4.2.3.2 EPT Taxa

Whereas the DMT metric assessed the macroinvertebrate community based on presence and abundance, the EPT taxa comparison is an assessment examining the presence (richness) of potentially sensitive taxa that are not necessarily dominant in the sample. Ephemeroptera (mayfly), Plecoptera (stonefly), and Trichoptera (caddisfly) taxa are important, sensitive, and valuable for use in biomonitoring (Lenat 1988; Rabeni et al. 1997). Abundance and taxa richness of mayflies; the number of taxa in the orders Ephemeroptera, Plecoptera, and Trichoptera; and total taxonomic richness were the best indicator metrics for detecting heavy metals pollution in streams in earlier studies (Clements et al. 2000; Hickey and Clements 2009; Poulton et al. 2009). The richness of EPT orders was compared to BIOREF streams to identify overall similarities to the reference condition. Secondly, comparisons were made among stations to identify similarities or differences that may identify areas of interest. Thirdly, taxa that were present at stations may identify some level of tolerance to stressors.

Ephemeroptera/Heptageniidae Richness

Mayfly taxa are generally considered to be sensitive to pollution or disturbance (Lenat 1988), and they are also very sensitive to heavy metals pollution (Burrows and Whitton 1983; Carlisle and Clements 1999; Clements et al. 1988; Clements 1994; Clements and Kiffney 1995; Clements et al. 2000; Kiffney and Clements 1994; Soucek et al. 2000; Poulton et al. 2009). At a finer taxonomic scale, the family Heptageniidae (flathead mayflies) within the Ephemeroptera, is generally considered to be sensitive to heavy metals pollution (Clements et al. 2000). Given that the extensive mining has occurred in the Fredericktown area, heavy metals pollution is a potential issue.

The number of mayfly taxa present in BIOREF streams was much greater than the Fredericktown area streams. Fall BIOREF streams of the EDU contained 28 Ephemeroptera, which was over two fold higher than the nearest test station. In the spring, BIOREF streams contained 36 mayfly taxa, which again was over twice that of the any test station. The lower taxa richness of Ephemeroptera at test stations during both seasons suggests the presence of a substantial and continuous influence in all Fredericktown area streams.

Differences in the number of Ephemeroptera taxa within and among LSFR and Logtown Branch stations may identify areas of influence. In the fall, LSFR #2 contained 14 mayfly taxa, which was relatively similar to LSFR #1 that had 16. Logtown Branch contained eight mayfly taxa in the fall. In the spring, both LSFR stations had 15 mayfly taxa, compared to Logtown Branch that contained six. Consistently higher and similar numbers of mayfly taxa between LSFR stations

suggest there was no new influence added between the stations that would have affected the presence of Ephemeroptera. Mayfly taxa were consistently and substantially influenced in Logtown Branch, but that influence did not obviously carry into the mayfly population in LSFR (#1).

The number of Ephemeroptera at Shays Creek stations followed an interesting trend that may identify influences. Shays Creek #2 had four mayfly taxa in the fall, and 10 were found in Shays Creek #1. In the spring, Shays Creek #2 supported three Ephemeroptera, and downstream Shays Creek #1 had six. Consistently fewer mayfly taxa upstream than downstream in both seasons suggests there is a constant source of effect located upstream or within Shays Creek #2. Conversely, more mayfly taxa were consistently found downstream, which suggests there was some level of recovery, presumably due to distance from a source.

Heptageniidae taxa richness followed interesting trends among test stations compared to BIOREF streams in both seasons. Both fall and spring BIOREF samples had eight Heptageniidae taxa, which is twice the number found at any of the Fredericktown area streams in either season. It is apparent that Heptageniidae taxa were continuously inhibited by a stressor present at all of the Fredericktown area streams.

The number of Heptageniidae taxa varied between LSFR stations and Logtown Branch. In the fall, both LSFR stations had four flathead mayfly taxa, whereas Logtown Branch had a single heptageniid taxon. In the spring, LSFR #2 contained two flathead mayfly taxa, and downstream LSFR #1 had four mayfly taxa. Logtown Branch again contained only a single mayfly taxon. Heptageniidae at LSFR #2 may be intermittently affected (spring) by some additional influence upstream. Heptageniidae taxa in Logtown Branch were consistently influenced by some additional input. Neither the additional influence upstream in LSFR #2 or upstream in Logtown Branch appeared to negatively affect flathead mayfly taxa downstream in LSFR #1.

Heptageniid mayfly taxa followed an increasing trend among stations in Shays Creek. Shays Creek #2 contained no Heptageniidae mayflies in the fall, but downstream Shays Creek #1 had three flathead mayfly taxa. In the spring, Shays Creek #2 again had no flathead mayfly taxa, and Shays Creek #1 had two. The continuous absence of these mayfly taxa upstream suggests the source or stressor is located upstream or within Shays Creek #2. Presence of some heptageniids downstream during both seasons indicates there may be a level of recovery, presumably due to distance from the upstream influences.

Plecoptera Richness

Stonefly taxa are generally considered good indicators of water quality (Lenat 1988); they range from sensitive (Clements et al. 2000) to highly sensitive (Burrows and Whittton 1983; Kiffney and Clements 1994; Poulton et al. 2009) to metals contamination in streams. However, Malaj et al. (2012) noted that one stonefly species in this genus (*Acroneuria lycorias*) is one of the more tolerant stonefly taxa to metals pollution.

The number of Plecoptera taxa present in BIOREF streams was much greater than the test streams. In aggregate, fall BIOREF samples contained five stonefly taxa, but LSFR #1 was the only station to have a Plecoptera taxon (*Acroneuria* sp.) among Fredericktown area stations. The low number of stonefly taxa at test stations in the fall may be a function of their life history or emergence (Poulton and Stewart 1991), which is a possibility as stoneflies were also rarely found in BIOREF samples of the EDU. In the spring, however, there were 16 stonefly taxa among BIOREF streams, which was slightly less than twice the number found at any Fredericktown area stream in this project. The number of stonefly taxa was substantially lower than would be expected at all stations, which implies a general stressor was limiting their presence.

Stonefly richness compared among stations may identify areas of influence. Stonefly taxa at LSFR/Logtown Branch that were observed in the fall are not discussed further due to their absence at all but one station (LSFR #1). In the spring, LSFR #2 had nine stonefly taxa, compared to LSFR #1 and Logtown Branch, both of which had six. A substantial decrease from upstream to downstream LSFR suggests that some additional influence, perhaps contributed by Logtown Branch, may have influenced their presence downstream LSFR #1 station. Stoneflies also were not observed in Shays Creek in the fall, but they were present in spring. Shays Creek #2 contained two stonefly taxa, and downstream Shays Creek #1 had three stonefly taxa. A lower number of stonefly taxa upstream compared to downstream suggests there was a limiting source present upstream or within Shays Creek #2; there may also be some level of recovery from those influences downstream at Shays Creek #1, presumably due to distance from a source. It is also possible, however, the difference of a single stonefly taxon was the result of sample variability between sites.

Trichoptera Richness

The number of Trichoptera taxa was much higher in BIOREF streams than all test streams. In the fall, BIOREF streams contained 21 caddisfly taxa, which was approximately 3-fold higher than any of the test stations. The spring BIOREF samples had 26 caddisfly taxa, approximately 2.5 times more than of any test station. Continuously higher numbers of Trichoptera in BIOREF streams than all test stations suggest some area-wide influence is inhibiting their presence in all Fredericktown area streams.

The number of Trichoptera taxa was generally similar among LSFR and Logtown Branch stations. In the fall, the upstream LSFR #2 had seven caddisfly taxa compared to five at LSFR #1. At the same time, Logtown Branch had eight caddisfly taxa. In the spring, LSFR #2 contained 11 caddisfly taxa, which was slightly higher than the 10 found in LSFR #1. Logtown Branch had nine caddisfly taxa, slightly fewer than both LSFR stations during that season. Although there may have been some influence on the community at LSFR #1 in the fall, it was not obviously caused by Logtown Branch. This suggested there was no additional influence affecting LSFR #1 or that Trichoptera taxa were generally tolerant of those influences. In fact, caddisflies did not react in a clear trend to suggest some influence, and they are apparently not as sensitive to influences as mayfly and stonefly taxa appeared to be. This is consistent with a study by Clements et al. (2000), in which the authors considered caddisfly taxa to be the least responsive to metals contamination among the three EPT orders.

Trichoptera taxa numbers fluctuated slightly between seasons among Shays Creek stations. Shays Creek #2 contained five caddisfly taxa, and downstream Shays Creek #1 had seven in the fall. In the spring, Shays Creek #2 had 11 caddisfly taxa, while Shays Creek #1 supported nine taxa. Again, there appears to be a lack of consistency between seasons, similar to Ephemeroptera, Heptageniidae, and Plecoptera trends shown earlier. This could be due to a lack of additional influences; however, responses by previously discussed taxa suggested otherwise. A more probable suggestion is that Trichoptera may not be particularly sensitive to that “additional influence” apparently affecting other taxa at these stations. Malaj et al. (2012) suggested caddisfly taxa may not be good indicators of metals contamination, which would be consistent if metals pollution were that additional source of effect.

EPT Taxa Response

The aquatic life stages of these three insect orders are generally considered to be intolerant of many types of pollution (Lenat and Penrose 1996), although sensitivity to different types of pollution varies among taxa in these insect orders (PDEP 2012). The DMT comparison presented earlier identified taxa that were apparently affected by or were sensitive to an influence at particular stations, based on their presence and abundance. Here, the EPT taxa examination was based on presence of these taxa within potentially sensitive orders. Trends using the EPT taxa richness suggested that all of the Fredericktown area streams were affected by some factor(s) not present or influential in BIOREF streams. Among stations, Logtown Branch and Shays Creek #2 macroinvertebrate communities appeared to be affected by an additional influence, having fewer Ephemeroptera, Heptageniidae, and Plecoptera taxa than LSFR stations or Shays Creek #1, similar to what was observed earlier using DMT taxa. Presence of taxa at these stations suggests they are tolerant of these additional influences.

Ephemeroptera

The mayfly taxa *Paraleptophlebia* sp. and *Dipheter* sp. were unique to Logtown Branch in the fall, whereas *Stenonema femoratum*, *Baetis* sp., *Centroptilum* sp., *Tricorythodes* sp., *Caenis anceps*, and *C. latipennis* were found in both LSFR and Logtown Branch. *Ameletus* sp. and *Dipheter* sp. were found only in Logtown Branch in the spring, and *S. femoratum*, *Centroptilum* sp., Leptophlebiidae, and *Plautitus* sp. occurred at both LSFR and Logtown Branch. Presence of these taxa implies they are tolerant of general and additional influences in both LSFR and Logtown Branch. Note that *S. femoratum* was the only Heptageniidae found in Logtown Branch in both seasons.

Several Ephemeroptera taxa were present at Shays Creek #2. *Acentrella* sp. and Leptophlebiidae were found only at Shays Creek #2 in the fall, while *Baetis* sp. and *C. latipennis* occurred at both the upstream and downstream stations. *Centroptilum* sp. and *Leptophlebia* sp. were unique to Shays Creek #2 in spring, and *C. latipennis* again occurred in both stations. Presence of these Ephemeroptera suggests they are tolerant of stressors in Shays Creek #2.

Heptageniidae

Within the Ephemeroptera, taxa in the family Heptageniidae (flathead mayfly) are generally considered to be sensitive to heavy metals pollution and a better indicator of metals pollution

than dominant mayfly taxa (Clements et al. 2000). In this examination of EPT, we found only one Heptageniidae taxon (*S. femoratum*) in Logtown Branch and none in Shays Creek #2 during either season. Presence of this single species suggests it is tolerant of influences there, and the paucity of heptageniid taxa suggests that other heptageniid taxa are sensitive to the influences found at these streams. Both Logtown Branch and Shays Creek are directly linked to mine-related contributors in their watershed. Mine LaMotte drains into the Slime Pond, which then flows into Shays Creek, and Catherine Mine is located near the source of Logtown Branch.

In contrast, LSFR #2 and LSFR #1 each supported several heptageniids. Station LSFR #2 samples had *Leucrocuta* sp., *M. pulchellum*, *Stenacron* sp., and *S. femoratum* in the fall and *Hexagenia* sp., *M. pulchellum*, and *S. femoratum* in spring. Station LSFR #1 had *M. pulchellum*, *Stenacron* sp., and *Stenonema femoratum* in both seasons; *Leucrocuta* sp. was found downstream in fall and *M. terminatum* was found downstream in spring. Presence of these taxa and absence of all but *S. femoratum* at Logtown Branch, suggests these taxa are intolerant of sources in Logtown Branch, and that LSFR stations are not subjected to the same influence or intensity of impact as Logtown Branch. Shays Creek #1 had additional heptageniids that were not found in Shays Creek #2 upstream. *Stenacron* sp. and *M. pulchellum* were found consistently, and *Leucrocuta* sp. was present in the fall. Contrasted with Shays Creek #2, which had no flathead mayfly taxa, it is apparent that the downstream sample reach is not subjected to the intensity of effects that are present upstream.

Past observations in mine-related studies (MoDNR 2004a; MoDNR 2004b; MoDNR 2010a; MoDNR 2013a; MoDNR 2013b; MoDNR 2015a; MoDNR 2018) suggested that *M. mediopunctatum* was particularly sensitive to mine-related influences, whereas the congeneric *M. pulchellum* appeared to be much more tolerant. Of the heptageniid mayflies, *M. mediopunctatum* commonly occurs in BIOREF streams of the Ozark/Upper St. Francis/Castor EDU and should occur in Fredericktown area streams. Yet it was not found in any test station in either season. Similar to the earlier studies of mine-related projects, *M. pulchellum* occurred at several stations; *M. pulchellum* tends to increase in abundance as *M. mediopunctatum* decreases. Loss of a species within the family and a substantial increase in abundance of another species within that same family may mask changes in the community structure when only using family level identification. This is consistent with findings of Sumi et al. (1991), who noted mayflies with higher tolerances to metals will increase as more sensitive mayflies decrease in dominance. Yet even *M. pulchellum* did not occur at either Logtown Branch or Shays Creek #2. The implication is that Logtown Branch and Shays Creek #2 are subject to an additional influence, perhaps related to heavy metals, that excludes even a potentially metals tolerant mayfly.

Plecoptera

No Plecoptera were present in the Logtown Branch or LSFR #2 fall samples, and only one stonefly taxon was found in the LSFR #1 sample. As a result, there can be no presence/absence analysis of stonefly taxa among Logtown Branch or LSFR stations for the fall. Plecoptera were found in common to both LSFR and Logtown Branch spring samples. No stoneflies were unique to Logtown Branch. *Perlesta* sp. (Perlidae), *Amphinemura* sp., *Isoperla* sp., and *Hydroperla*

crosbyi were common to both LSFR and Logtown Branch stations. Perhaps these taxa are tolerant of influences in these streams.

In the fall, no Plecoptera were found in either Shays Creek station. As mentioned earlier stoneflies can be rare in the fall samples, which could be a function of stonefly life history (Poulton and Stewart 1991). *Perlesta* sp. and *Amphinemura* sp. were present at Shays Creek #2 and Shays Creek #1 in the spring. Leuctridae were also found in downstream Shays Creek #1. Presence of the two taxa upstream suggests they are tolerant of influences there. Absence of Leuctridae upstream suggests they may be somewhat intolerant of influences, and their presence downstream suggests there be some recovery that allows their presence. Many stonefly taxa that occurred in BIOREF streams were absent from both Shays Creek stations, suggesting they were sensitive to influences found in these stations.

Trichoptera

As mentioned earlier, Trichoptera richness did not follow obvious trends, and a large number were present in the Logtown Branch/LSFR association. The caddisfly taxa *Ceratopsyche* sp., *Hydroptila* sp., and *Ptilostomis* sp. were unique to Logtown Branch in the fall. *Chimarra* sp., *Cheumatopsyche* sp., *Triaenodes* sp., *Oecetis* sp., and *Polycentropus* sp. were found in LSFR and Logtown Branch in the fall. In the spring, *Isonychia* sp., *Platycentropus* sp., and *Lepidostoma* sp. were only found in Logtown Branch, and *Rhyacophila* sp., *Cheumatopsyche* sp., *Hydroptila* sp., *Triaenodes* sp., *Nectopsyche* sp., and *Polycentropus* sp. were common to both LSFR and Logtown Branch. The diversity of caddisfly taxa suggests that many caddisfly taxa are somewhat tolerant to influences in Logtown Branch and LSFR. As mentioned earlier, Clements et al. (2000) found Trichoptera to be the least sensitive to metals contamination among EPT taxa studied.

Caddisfly taxa were prevalent in Shays Creek. *Pycnopsyche* sp. was unique to Shays Creek #2. *Chimarra* sp., *Cheumatopsyche* sp., *Hydropsyche* sp., and *Oecetis* sp. were common to both Shays Creek stations in the fall. *Ptilostomis* sp., *Isonychia* sp., and *Polycentropus* sp. were unique to Shays Creek #2 in the spring, and *Rhyacophila* sp., *Chimarra* sp., *Cheumatopsyche* sp., *Hydropsyche* sp., *Hydroptila* sp., *Pycnopsyche* sp., *Oecetis* sp., and *Helicopsyche* sp. were common at both stations in the spring. These caddisfly taxa found at Shays Creek #2 or both stations appear to be tolerant of additional and general influences.

Many more EPT taxa occurred in LSFR stations and Shays Creek #1 (with the exception of Trichoptera in spring) that were not present in Logtown Branch or Shays Creek #2. All things being equal, these taxa may be identified as sensitive to the additional influence at Logtown Branch and Shays Creek #2.

Overall Secondary Metrics

Overall, secondary metrics provided further insight into the macroinvertebrate communities at all streams in the Fredericktown area project. The first was that macroinvertebrate communities at all stations were substantially different from BIOREF streams of the EDU, some more so than others. The LSFR stations were not similar to BIOREF streams, more so for LSFR #2 in the fall

and LSFR #1 in spring. Logtown Branch appeared to be more affected than either LSFR station in both seasons. Likewise, although both Shays Creek station communities were substantially different from BIOREF stream communities, secondary metrics suggested Shays Creek #2 upstream was more heavily influenced than the downstream Shays Creek #1. Importantly, Logtown Branch and Shays Creek #2 were apparently subjected to additional influences not present or as prevalent in the remaining stations. As mentioned earlier, Catherine Mine is in the Logtown Branch watershed and is presently used as a repository for potentially mine related contaminated products. The Slime Pond (Mine LaMotte tailings pond) is situated within Shays Creek and immediately upstream of Shays Creek #2. Impoundments alone can affect the hydrology and aquatic communities of stream systems (Arnwine et al. 2006). In addition, the Slime Pond was created and used in the process of heavy metals mining in the past, and the surrounding area consists of a large mine-waste chat pile. These two mine-related sources may be related to the additional source that has apparently altered macroinvertebrate communities in Logtown Branch and Shays Creek.

4.2.4 General Water Quality

Surface water physicochemical constituents were examined for all Fredericktown area samples collected in 2015 and 2016. All general water quality constituents were within WQSs (MoDNR 2012b), where they were defined. However, several analytes exceeded the EPA suggested guidelines (EPA 2000). Nutrients and associated chemical parameters followed particular trends in the Logtown Branch, LSFR stations, and Shays Creek stations that may identify sources or areas of interest. Trends in sulfate concentrations may potentially identify sources, types of influences, and areas of interest.

4.2.4.1 Nutrients

All surface water physicochemical analytes from Logtown Branch, LSFR, and Shays Creek stations were within Missouri WQSs (MoDNR 2012b). However, several nutrients and variables that can be associated with the presence of nutrients (i.e. “associated constituents,” which include turbidity and chloride for this discussion) were outside EPA suggested guidelines (EPA 2000) or followed trends that identified additional potential influences and areas of interest.

Nutrients and associated constituents followed trends in the Logtown Branch/LSFR association that may identify areas of influence or interest. None of the nutrients exceeded EPA guidelines in fall Logtown Branch samples, and only turbidity exceeded the EPA suggested guidelines in the spring. Nutrient concentrations and associated constituents were not obvious contributors to the AQL beneficial use designations at Logtown Branch in the fall or spring. However, at both LSFR stations, constituents such as turbidity, total nitrogen, and total phosphorus were consistently higher than EPA suggested guidelines in the spring. Total nitrogen concentrations were similar between the LSFR stations and below laboratory practical quantitation limits at Logtown Branch. Ammonia as N was detected at LSFR stations in the fall, but it was below detectable concentrations at Logtown Branch in both seasons. With no obvious contributions from Logtown Branch, the source for nutrients was apparently upstream of or within LSFR #2. As mentioned earlier, cropland constitutes approximately 2.4 percent of the watershed, and grassland makes up 34.3 percent. Contributions of nutrients upstream of LSFR #2 may be due to

land applying fertilizer, grazing, septic systems, or other sources within the watershed. Nutrients may contribute to suboptimal MSCI scores with elevated BI metric values, and overall community differences between BIOREFs and Fredericktown area streams, excluding Logtown Branch. Nutrients and associated constituent concentrations should be assessed in LSFR and its tributaries upstream of LSFR #2 to identify trends and sources.

Nutrients and associated constituent trends may identify potential influences in the Shays Creek drainage. Turbidity and total phosphorus were consistently above EPA guidelines in Shays Creek #2, perhaps due to influences upstream of or within the station. Turbidity, total phosphorus, total nitrogen, and nitrate+nitrite as N were consistently above respective EPA guidelines downstream in Shays Creek #1 and were consistently higher than Shays Creek #2. Consistently higher nutrient concentrations at the downstream station indicated there was a local organic input downstream from Shays Creek #2 and upstream of or within Shays Creek #1. The watershed within and between the two stations consists of grazed pasture upstream of and including Shays Creek #1. This land use could account for higher nutrient concentrations, including the slight increase in ammonia and chloride in the fall. Elevated nutrient concentrations may have affected the macroinvertebrate community at Shays Creek #1 in both seasons. Nutrients and associated constituents should be periodically analyzed at Shays Creek #1, as well as downstream from Shays Creek in Village Creek.

Interestingly, higher concentrations of nutrients were observed at LSFR stations and Shays Creek #1 than at the two stations with an apparent “additional influence.” Perhaps nutrients were indicative of the overall or general influence observed in the differences in macroinvertebrate communities between BIOREF streams and Fredericktown area streams using primary and secondary metrics, such as the BI metric values at all stations. Elevated total nitrogen, ammonia, and nitrate+nitrite as N have been observed in significantly higher concentrations in mining sites compared to references (Allert et al. 2009) and have coincided with the presence of heavy metals in mine-related streams in southeast and southwest Missouri. The Allert et al. (2009) observations are not consistent with this study, as nutrients and associated constituents were usually observed in much lower concentrations at Logtown Branch and Shays Creek, which are direct conduits draining substantial mine-related areas. Perhaps lower nutrient concentrations at these two stations indicate there is little metals influence at these two stations, identify mine-related remediation efforts in these areas, or just suggest there were fewer organic related sources, such as agriculture, septic systems, or WWTFs in their watersheds. Conversely, nutrient trends suggest organic influences are more prevalent and may be at least partially responsible for the altered community compositions at LSFR #2, LSFR #1, and Shays Creek #1

4.2.4.2 Sulfate

Sulfate is an analyte commonly found with urban related influences, and is closely associated with heavy metals mining in southeast and southwest Missouri (Allert et al. 2008, 2011; Shaider et al. 2014). Sulfate in streams is commonly associated with heavy metals mining through oxidation of pyrite and other metal sulfide minerals, producing sulfate and releasing co-occurring trace metals (Brumbaugh et al. 2007; Allert et al. 2008; Schaidler et al. 2014). Concentrations of metals and sulfate in sediment interstitial and surface waters have generally tracked closely with

metals concentrations in benthic sediments (Brumbaugh et al. 2007; Allert et al. 2008, 2011). Sulfate concentrations alone were well below Missouri WQS (MoDNR 2012b) and were not considered to be detrimental to the community composition among Fredericktown area streams. However, concentrations followed specific trends that potentially identified mine-related sources in two of the Fredericktown area streams.

Sulfate concentrations followed a consistent trend that may identify a source related to metals mining in the Logtown Branch/LSFR association. Sulfate concentrations were consistently 2-2.5 times higher in Logtown Branch than either of the two LSFR stations that bracketed its confluence. Sulfate concentrations in LSFR #2 (upstream of Logtown Branch) were consistently slightly lower than those observed in LSFR #1 (downstream of Logtown Branch). The increasing trend from upstream to downstream suggests that Logtown Branch may have contributed sulfate and potentially other mine-related constituents to LSFR. As mentioned, Logtown Branch is a receiving stream from Catherine Mine, which may be a source for this constituent.

Sulfate concentrations in Shays Creek followed a consistent longitudinal trend that may identify a source for mine-related constituents. Sulfate concentrations were 20 to 50 percent higher upstream at Shays Creek #2 than were observed downstream at Shays Creek #1. This decreasing longitudinal trend suggests there was a consistent source for sulfate and potentially mine-related constituents upstream of or within Shays Creek #2. Sulfate concentrations being consistently lower downstream at Shays Creek #1 implied there were no obvious additional contributions of sulfate and mine-related constituents between the two stations. As mentioned, Shays Creek #2 receives continuous flow from the Slime Pond, a Mine LaMotte tailings pond with a nearby chat pile. The Slime Pond may be a continuous source of mine-related constituents to Shays Creek.

4.3 Dissolved Metals

Dissolved metals were observed at all Fredericktown area stations in both seasons. All metals observed are associated with heavy metals mining, yet all were well below Missouri's acute and chronic toxicity WQS thresholds (MDNR 2014) in both seasons. Dissolved metals were not obvious contributors to the macroinvertebrate community composition in the concentrations observed at Logtown Branch, LSFR, or Shays Creek. However, concentrations within, and trends among, stations identified potential sources for heavy metals that may affect the aquatic community composition under suitable conditions.

4.3.1 Logtown Branch and LSFR

Dissolved metals concentrations among stations may identify sources in the Logtown Branch/LSFR association. Copper and nickel levels were consistently 2-3 times higher in Logtown Branch than in LSFR stations, identifying a continuous source within the Logtown Branch watershed. Copper concentrations were consistently similar between both LSFR stations, which suggests Logtown Branch discharge did not contribute a substantial amount to LSFR #1 during sampling. However, nickel concentrations were consistently slightly higher in LSFR #1 than upstream in LSFR #2, implying that Logtown Branch discharge consistently contributed nickel to LSFR. Although concentrations were low, the continuous input and fluctuating concentrations suggests the Logtown Branch watershed has the potential to affect the

macroinvertebrate community given suitable conditions. Dissolved metals should be periodically analyzed in Logtown Branch and upstream in its headwaters to identify trends and sources.

Dissolved arsenic and zinc were also present in the Logtown Branch/LSFR association and may identify another area of interest. Dissolved arsenic was observed in the same concentration at both LSFR stations, and it was not detected in Logtown Branch in the fall. Arsenic was not detected at all three stations in spring. Dissolved zinc was observed in very low concentrations that decreased from LSFR #2, LSFR #1, and Logtown Branch respectively in the fall; in the spring, zinc was observed only in Logtown Branch. This pattern suggests there is an intermittent source (fall) for arsenic and zinc upstream of or within LSFR #2 and LSFR #1 that is not apparently contributed by Logtown Branch. Zinc was consistently present in Logtown Branch, but was not obviously contributed to LSFR in either season. These metals were present in low concentrations, but identify potential sources upstream of LSFR #2 and within Logtown Branch watershed, as well as the potential for influential fluctuations given suitable conditions. Dissolved metals concentrations should be periodically analyzed upstream of and including LSFR #2 and downstream of LSFR #1 to identify sources and trends.

Interestingly, dissolved iron and manganese concentrations were much lower in Logtown Branch than either LSFR station, which may identify a specific source for metals concentrations. Iron and manganese concentrations in Logtown Branch ranged from 3 to 50 percent of LSFR concentrations. Generally low concentrations of iron, manganese, and all other dissolved metals in Logtown Branch may be a result of efforts to contain mine-related influences in the Catherine Mine area. They may also identify their specific source. Iron and manganese oxides are important in decreasing mobility and bioavailability of other heavy metals (Horowitz 1985; Shaider et al. 2014). Iron and manganese play a role maintaining low levels of other heavy metals, such as lead, by complexing and precipitating them out of the fraction. In Tar Creek, a stream in the Tri-State Mining District, Shaider et al. (2014) found much lower concentrations of iron and manganese in runoff associated with mine-waste piles, compared to much higher concentrations in water associated with surface and subsurface mine drainage. They suggested that oxidation and reprecipitation of iron within the piles under oxic conditions related to periodic wetting and drying may explain the very low iron concentrations in mine-waste pile runoff. Findings by Shaider et al. (2014) suggest the source for these and other dissolved metals may be from mine-waste piles within Logtown Branch (bars) or its watershed, which includes the Catherine Mine area.

4.3.2 Shays Creek

All of the dissolved metals analyzed in Shays Creek were below Missouri's WQS (MoDNR 2014); however, several dissolved metals were present and exhibited trends that potentially identify heavy metal sources. Dissolved arsenic, copper, and nickel concentrations were consistently higher in Shays Creek #2 than the downstream station. Arsenic and copper were approximately 2-times higher, and nickel concentrations were 2-4 times higher upstream than downstream at Shays Creek #1. Additionally, dissolved cobalt was observed in the spring only at Shays Creek #2. Higher concentrations upstream than downstream suggest their source is upstream in the watershed, adjacent to, or within Shays Creek #2. Lead and zinc concentrations however, were generally similar or only slightly different, fluctuating depending on seasons

between upstream and downstream stations. The source for these two metals may have been related to runoff between the two stations or within the entire stream reach from benthic sediments (i.e. tailings) deposited as a result of past mine-related practices in the area.

Dissolved metals concentrations followed trends potentially related to discharge, which may in turn identify their sources. As would be expected if metals were mobile and associated with greater runoff within the watershed and higher discharge, dissolved cobalt, copper, and nickel concentrations were higher in spring, when flow was greater, than fall. This suggests a source for metals may be uncontrolled runoff from the watershed adjacent to Shays Creek #2 or through discharge (spill water) from the Slime Pond. Conversely, dissolved arsenic, lead, and zinc concentrations were generally higher in fall during low flow conditions. Higher concentrations during low flow periods suggests their sources are potentially instream, concentrated and released given suitable conditions from metals-rich benthic fine sediment. Additionally, during low flow, arsenic and zinc concentrations were higher upstream than downstream, which suggests the instream source was more prevalent upstream than downstream. Lead, however, was observed in a higher concentration downstream than upstream during the fall, identifying its instream source as being prevalent potentially throughout the length of Shays Creek. Dissolved metals should be monitored in Shays Creek, including the Slime Pond and upstream if possible, to identify trends and sources.

4.4 Fine Sediment: Total Metals Characterization

Benthic fine sediment was collected in the fall at all Fredericktown area stations and analyzed for total arsenic, cadmium, copper, lead, nickel, silver, and zinc. Of these metals, total arsenic, copper, lead, and nickel were found in notable concentrations. Individual PEC and mixture or combined metals effects thresholds ($\sum \text{PEQ}_{\text{Cd, Pb, Zn}}$, and mean PEQ) were compared to results from all streams and stations; metals present above or near threshold concentrations were highlighted. Longitudinal trends are also discussed if notable. Results are grouped by the Logtown Branch/LSFR association and Shays Creek stations.

4.4.1 Logtown Branch and LSFR

Benthic fine sediment from Logtown Branch contained several metals that were observed in notable concentrations. Total lead and nickel concentrations were well above their respective PECs, which suggests they are potentially toxic to the aquatic community. Perhaps these metals are the additional influence (not prevalent in LSFR) detected earlier that shaped a much different community composition than was observed in BIOREF streams of the EDU. Total copper was slightly below the PEC, and the arsenic concentration was approximately half of the PEC at Logtown Branch. The mixture or combination of cadmium, lead, and zinc did not exceed the $\sum \text{PEQ}_{\text{Cd, Pb, Zn}}$ threshold, but it was near the mean $\text{PEQ}_{\text{metals}}$ threshold for all sampled metals. The general source for these fine sediment related metals may be Catherine Mine, upstream in the watershed. Fine sediment should be periodically collected at Logtown Branch and its headwaters to be analyzed for total metals concentrations to identify trends and sources.

Benthic fine sediment metals concentrations in LSFR stations did not exceed individual PEC thresholds or a mixture or combination thresholds, suggesting they were not obviously affecting

the aquatic macroinvertebrate community. However, higher concentrations of total arsenic, copper, lead, and nickel were observed downstream of Logtown Branch in LSFR #1 than LSFR #2. Logtown Branch appears to be the source for metals associated with fine sediment deposited in LSFR #1. Therefore, efforts that prevent metals-rich fine sediments from entering Logtown Branch will likely lessen the amount in LSFR #1 over time.

4.4.2 Shays Creek

All of the fine sediment associated metals analyzed were detected in Shays Creek, three of which were observed in potentially toxic concentrations. Total arsenic, lead, and nickel were detected above PEC thresholds at Shays Creek #2, which suggests each metal is found in a concentration that is potentially toxic to the aquatic community. The mixture of cadmium, lead, and zinc using the $\sum \text{PEQ}_{\text{Cd, Pb, Zn}}$ was not above the threshold because cadmium and zinc were low and only lead (among the three) exceeded the PEQ. However, when all metals ($n=7$) were taken into account, the mean $\text{PEQ}_{\text{metals}}$ exceeded the threshold, indicating that the mixture or combination of metals was also potentially toxic to aquatic life. Total metals concentrations associated with benthic fine sediment may have been the additional source (not prevalent LSFR) for effects identified earlier using secondary metrics. This station receives flow from the Slime Pond and is adjacent to a large Mine LaMotte tailings pile, either of which may contribute to the metals-rich fine sediment load in Shays Creek.

All of the metals analyzed, with the exception of silver, were detected downstream in Shays Creek #1. Of the metals detected, arsenic exceeded its PEC threshold and was considered potentially toxic to the aquatic community. However, arsenic was less than half of the concentration observed upstream. Lead was slightly below the PEC threshold at Shays Creek #1, and nearly 5-fold lower than upstream. Nickel was well below the PEC threshold in Shays Creek #1 and was likewise approximately 5-fold lower than upstream. The mixture or combination thresholds were not exceeded at Shays Creek #1. Although arsenic was found in potentially toxic concentrations, the longitudinal decrease (from upstream) in metals concentrations associated with benthic fine sediment suggests the community was less influenced and the station is farther from the metals source. Metals-rich fine sediment may be detained upstream and/or removed from Shays Creek to Village Creek downstream given suitable conditions. Fine sediment should be periodically collected at Shays Creek stations from this study, the Slime Pond, and Shays Creek upstream of the Slime Pond if possible, and analyzed for total metals concentrations to identify trends and sources. Fine sediment metals character should also be identified downstream of Shays Creek #1 in Village Creek.

4.5 Relationship between Dissolved and Total Metals

As mentioned earlier in the dissolved metals section (see Section 4.3.1), very low dissolved iron and manganese concentrations at Logtown Branch, relative to LSFR, may have identified mine waste piles or instream (bar) mine waste (Shaider et al. 2014) as specific sources for dissolved metals. Shaider et al. (2014) suggest iron oxide aggregate material is responsible for the transport of a significant fraction of particulate metals. Runoff of fine sediment in the watershed, wetting and drying of instream sediments, and reprecipitation may be contributing to the benthic metals character and potentially the dissolved metals in Logtown Branch.

At Shays Creek, fluctuations in dissolved metals concentrations among stations and seasons suggested that the source for dissolved arsenic, lead, and zinc may be instream, potentially throughout the watershed (see Section 4.3.2). In fact, benthic fine sediments contained metals, including total arsenic and lead, that were present in elevated to potentially toxic concentrations throughout the reach, with higher concentrations found upstream than downstream. This is consistent with the earlier suggestion potentially linking these dissolved metals with metals associated with benthic fine sediments.

Streambed sediments can represent a persistent reserve of exchangeable metals that can be remobilized, released to the water column, and cause delays in biological recovery following pollution source controls (Hamilton 2012). Besser et al. (2009a) saw toxicity variations due to remobilization of metals from manganese oxides in anoxic conditions. Although only a fraction of the metals present in sediments is bioavailable at any given time due to binding to particulate organic carbon, iron, manganese oxyhydroxides, and sediment burial (Costello and Burton 2014), trace contaminants associated with sediments will remain in the river-floodplain system and be subject to remobilization until stored deposits become depleted (Hamilton 2012; Moore and Langner 2012; Mebane et al. 2015).

Sediment metals loading due to precipitation of metals can be substantial and have effects on the benthic ecosystem (Shaider et al. 2014). Effects on aquatic life can persist well past the last active mining has taken place (Ryck and Whitley 1974; Chadwick et al. 1986; Hoiland et al. 1994) and can vary depending on geochemical and hydrologic factors (Brumbaugh et al. 2007; Poulton et al. 2009). Fine sediment pore water should be collected in Logtown Branch and Shays Creek, analyzed, and compared to toxicity thresholds (MacDonald et al. 2009).

Dissolved iron and manganese oxides are important in decreasing mobility and bioavailability of other heavy metals (Horowitz 1985; Shaider et al. 2014). Shaider et al. (2014) go on to say that high concentrations of iron oxides from mine drainage trap lead, cadmium, and zinc that originate from mine-waste piles. Removal of iron oxides associated with mine drainage before removing the mine-waste may therefore increase the mobility and bioavailability of heavy metals. This should be considered before mine waste is removed from these streams and watersheds.

5.0 Summary

1. Stream habitat was comparable to the SHAPP Control only at LSFR #1. Logtown Branch and LSFR #2 SHAPP scores (percentages) were slightly below the optimal range, which was at least partly related to heavy fine sediment deposition.
2. Stream habitat was well below the comparable SHAPP scoring range at Shays Creek #2 and Shays Creek #1, partly related to heavy fine sediment deposition.
3. The upstream LSFR station had fully supporting MSCI scores in both sample seasons, but the downstream LSFR station was partially supporting for both seasons. Logtown Branch, which is bracketed by the two LSFR stations, was fully supporting in the fall and partially supporting in spring.
4. Both Shays Creek stations had partially supporting MSCI scores during both seasons.

5. Stream size did not have an obvious effect on the original MSCI score at Logtown Branch, but it may have influenced the MSCI score at Shays Creek.
6. Dominant macroinvertebrate taxa (DMT) and EPT taxa analysis indicated that the macroinvertebrate communities at all study streams were substantially different from the BIOREF condition. Communities in Logtown Branch and Shays Creek #2 appeared to be more affected, and subject to an additional influence not prevalent than the remaining stations.
7. Nutrients were more prevalent at the two LSFR stations and Shays Creek #1 than the remaining study sites. Agriculture (grazing) is a likely source of nutrients for these sites.
8. Sulfate concentrations were highest at Logtown Branch and Shays Creek #2, potentially identifying metals influences.
9. All surface water dissolved metals were below Water Quality Standards thresholds.
 - a. Dissolved zinc, copper, and nickel were consistently present in Logtown Branch.
 - b. Of the three metals, only dissolved nickel was apparently contributed to LSFR #1 by Logtown Branch.
 - c. Dissolved arsenic and zinc were intermittently present at LSFR #2 and LSFR #1 that were not contributed by Logtown Branch.
 - d. Dissolved arsenic, copper, and nickel were consistently observed in both Shays Creek stations; higher concentrations were present at Shays Creek 2 than Shays Creek #1.
 - e. Cobalt was observed only at Shays Creek #2 in spring.
 - f. At Shays Creek #2, cobalt, copper, and nickel were found in higher concentrations in spring, suggesting their presence or prevalence is related to higher runoff and discharge.
 - g. Dissolved arsenic, lead, and zinc concentrations were generally higher in fall, potentially identifying an instream concentrated source in Shays Creek.
 - h. Arsenic and zinc concentrations were higher upstream in Shays Creek.
 - i. Lead was higher downstream in fall suggesting an instream source throughout Shays Creek.
10. Benthic sediment total metals were detected at the following sites:
 - a. Logtown Branch: lead and nickel exceeded thresholds; copper was near the threshold, and arsenic was approximately half of threshold. Mean PEQ_{metals} was near the mixture or combination of all metals threshold.
 - b. LSFR: did not exceed thresholds. However arsenic copper, lead, and nickel were higher downstream (#1) than upstream (#2); Logtown Branch was the potential source.
 - c. Shays Creek #2: arsenic, lead, and nickel exceeded thresholds; mean PEQ_{metals} exceeded the mixture or combination of all metals threshold.
 - d. Shays Creek #1: arsenic exceeded the threshold, and lead was near the PEC.

6.0 Conclusions

The objectives have been addressed. The stream habitat, macroinvertebrate community, and physicochemical water quality have been assessed. Dissolved metals concentrations in the surface water and total metals concentrations associated with the fine sediment (i.e. metals character) have been identified.

Testing of the null hypotheses resulted in the following:

- 1) Stream habitat quality at all streams will be comparable to the stream habitat control.

This null hypothesis was rejected for all stations except LSFR #1.

- 2) Macroinvertebrate Stream Condition Index (**MSCI**) scores will indicate that Logtown Branch, Little St. Francis River, and Shays Creek are fully supporting of the beneficial use – AQL, and individual biological metric scores will be within the optimum scoring range of wadeable/perennial reference stream biological criteria during the fall and spring seasons.

The null hypothesis being fully supporting was rejected at several stations:

- Logtown Branch was fully supporting of the beneficial use designation in the fall and partially supporting in the spring;
- LSFR #2 was consistently fully supporting;
- LSFR #1 was consistently partially supporting;
- Shays Creek #2 was consistently partially supporting;
- Shays Creek #1 was consistently partially supporting.

The null hypothesis of individual metrics being in the optimal range was rejected due to at least two individual biological metric scores that were below the optimum scoring range at all stations in both seasons.

- 3) The biological support categorization for smaller test streams (Logtown Branch and Shays Creek) will not be influenced by stream size.

The null hypothesis was rejected for both Shays Creek stations in the spring season.

The null hypothesis was not rejected for Logtown Branch in either season.

- 4) Secondary metrics (dominant macroinvertebrate taxa and EPT taxa compositions) will indicate that Logtown Branch, Little St. Francis River, and Shays Creek macroinvertebrate communities are similar to BIOREF streams.

The null hypothesis was rejected for all streams and stations.

- 5) Physicochemical water quality parameters will be within acceptable limits as specified in Missouri's Water Quality Standards (**WQS**; MoDNR 2012b) and will not be notable using suggested guidelines.

The null hypothesis for WQSs MoDNR (2012b) was not rejected for all stations.

The null hypothesis for notable parameters (EPA [2000] suggested guidelines) was rejected for:

- Logtown Branch turbidity in spring;
- LSFR #2 turbidity and TP in fall; turbidity, TN, and TP in spring;
- LSFR #1 turbidity and TP in fall; turbidity, TN, and TP in spring;
- Shays Creek #2 turbidity, TP, and TN in both seasons;
- Shays Creek #1 turbidity, TP, TN, and nitrate + nitrite as N in both seasons.

- 6) Dissolved metals in the surface water at stations will be within acceptable hardness-dependent limits outlined in Missouri's WQS (MoDNR 2014) in Logtown Branch, Little St. Francis River, and Shays Creek stations.

The null hypothesis was not rejected for all dissolved metals at all stations in both seasons.

- 7) Total metals (i.e. arsenic, cadmium, copper, lead, nickel, silver, or zinc) concentrations associated with benthic fine sediment will be below potentially toxic threshold levels in Logtown Branch, Little St. Francis River, and Shays Creek.

The null hypothesis was rejected for:

- total lead and nickel in Logtown Branch;
- total arsenic, lead, and nickel in Shays Creek #2;
- total arsenic in Shays Creek #1.

7.0 Recommendations

- 1) Nutrients and associated constituent concentrations should be assessed in LSFR and its tributaries upstream of LSFR #2 to identify trends and sources.
- 2) Nutrients and associated constituents should be periodically analyzed at Shays Creek #1, as well as downstream from Shays Creek in Village Creek.

- 3) Sulfate concentrations and other physicochemical constituents should be analyzed in the Logtown Branch watershed and downstream in LSFR to identify trends and sources.
- 4) Sulfate concentrations and other physicochemical constituents should be analyzed in the Slime Pond and upstream Shays Creek, if possible (flow is intermittent upstream), to identify trends and sources.
- 5) Dissolved metals should be periodically analyzed in Logtown Branch and upstream in its headwaters to identify trends and sources.
- 6) Dissolved metals concentrations should be periodically analyzed upstream of and including LSFR #2 and downstream of LSFR #1 to identify sources and trends.
- 7) Dissolved metals should be monitored in Shays Creek, including the Slime Pond and upstream, if possible, to identify trends and sources.
- 8) Fine sediment should be periodically collected at Logtown Branch and its headwaters to be analyzed for total metals concentrations to identify trends and sources.
- 9) Prevent metals-rich fine sediments from entering Logtown Branch.
- 10) Metals-rich fine sediments should be prevented from entering Shays Creek.
- 11) Fine sediment should be periodically collected at Shays Creek stations, in the Slime Pond, and upstream Shays Creek, if possible, and analyzed for total metals concentrations to identify trends and sources.
- 12) Fine sediment metals character should be identified downstream of Shays Creek #1 in Village Creek.
- 13) Fine sediment pore water should be collected in Logtown Branch and Shays Creek, analyzed, and compared to toxicity thresholds (MacDonald et al. 2009).
- 14) Iron oxides associated with mine drainage should not be removed before the mine-waste, as it may increase the mobility and bioavailability of heavy metals.

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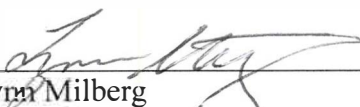
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Appendix A

**Macroinvertebrate Bench Sheet Report:
Fredericktown Area: Little St. Francis, Logtown Branch, and Shays Creek Stations,
Madison County, Missouri
Fall 2015 – Spring 2016**

Grouped by season and station (upstream to downstream)

Aquid Invertebrate Database Bench Sheet Report**Little St. Francis R [15039], Station #2, Sample Date: 9/22/2015 11:30:00 AM****CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence**

ORDER: TAXA	CS	NF	RM
"HYDRACARINA"			
Acarina	11	13	43
AMPHIPODA			
Hyaella azteca			21
BASOMMATOPHORA			
Ancylidae			1
Menetus			5
Physella			1
COLEOPTERA			
Ancyronyx variegatus		1	5
Berosus			2
Dubiraphia		8	28
Helichus lithophilus	6		
Microcylloepus pusillus	2		
Scirtidae			2
Stenelmis	14	3	2
DECAPODA			
Faxonius virilis			-99
DIPTERA			
Ablabesmyia	1	13	2
Anopheles			3
Ceratopogoninae	2	3	2
Chironomidae	3	8	4
Cladopelma		2	1
Cladotanytarsus	2	40	
Corynoneura	1	2	2
Cricotopus bicinctus	1		
Cricotopus/Orthocladius	6	3	7
Cryptochironomus	8	16	
Cryptotendipes		1	
Dicrotendipes		21	2
Dixella	1		2
Dixidae		4	
Hemerodromia	6	1	2
Hexatoma	2		

Aquid Invertebrate Database Bench Sheet Report**Little St. Francis R [15039], Station #2, Sample Date: 9/22/2015 11:30:00 AM****CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence**

ORDER: TAXA	CS	NF	RM
Labrundinia	1	1	12
Limnophyes		2	
Microtendipes	4		2
Nanocladius			1
Natarsia		1	
Nilotanypus	12	1	
Nilothauma			2
Paracladopelma		1	
Paralauterborniella		1	
Parametriocnemus	1		
Paratanytarsus	2	6	33
Phaenopsectra	4	1	2
Polypedilum aviceps		1	
Polypedilum fallax grp		1	
Polypedilum flavum	15	1	
Polypedilum halterale grp		11	1
Polypedilum illinoense grp	1	12	
Polypedilum scalaenum grp	5	4	
Pseudochironomus			1
Rheocricotopus		4	
Rheotanytarsus	108		
Saetheria	14		
Simulium	8		
Stempellina		3	
Stempellinella	8	40	14
Stenochironomus			1
Tabanus	-99		
Tanytarsus	110	64	38
Thienemanniella	5	4	1
Thienemannimyia grp.	5	2	
Tipula	2		
Tribelos			8
EPHEMEROPTERA			
Acerpenna	5		
Baetis	3		

Aquid Invertebrate Database Bench Sheet Report**Little St. Francis R [15039], Station #2, Sample Date: 9/22/2015 11:30:00 AM****CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence**

ORDER: TAXA	CS	NF	RM
Caenis anceps	4	1	1
Caenis latipennis	4	21	10
Centropilum	1	12	3
Ephemera simulans		2	
Eurylophella bicolor			2
Isonychia bicolor	18		
Leptophlebiidae	2	2	13
Leucrocuta	2		
Maccaffertium pulchellum	8		
Stenacron	1		
Stenonema femoratum		6	3
Tricorythodes	99	4	
HEMIPTERA			
Mesovelgia	1		
MEGALOPTERA			
Corydalus	2		
Sialis			-99
ODONATA			
Argia	1		5
Basiaeschna janata			-99
Boyeria	-99		
Calopteryx			-99
Enallagma			18
Gomphidae		1	4
Gomphus			-99
Hetaerina	1		
Macromia		1	-99
Progomphus obscurus	-99		
RHYNCHOBDELLIDA			
Glossiphoniidae			-99
TRICHOPTERA			
Cheumatopsyche	46		
Chimarra	7		
Cynellus fraternus			2
Hydropsyche	2		

Aquid Invertebrate Database Bench Sheet Report**Little St. Francis R [15039], Station #2, Sample Date: 9/22/2015 11:30:00 AM****CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence**

ORDER: TAXA	CS	NF	RM
Oecetis	9	2	1
Polycentropus			6
Triaenodes		2	12
TUBIFICIDA			
Aulodrilus			1
Branchiura sowerbyi			2
Enchytraeidae		1	
Tubificidae	3	3	4
VENEROIDA			
Corbicula	2	2	4
Pisidiidae		2	

Aquid Invertebrate Database Bench Sheet Report**Logtown Br [15038], Station #1, Sample Date: 9/22/2015 10:20:00 AM****CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence**

ORDER: TAXA	CS	NF	RM
"HYDRACARINA"			
Acarina	1	1	
AMPHIPODA			
Crangonyx	2		2
Hyalella azteca			6
Stygobromus	1	4	
BASOMMATOPHORA			
Menetus	3	7	17
Physella	10	3	11
COLEOPTERA			
Dubiraphia			8
Dytiscidae		3	2
Ectopria nervosa			1
Enochrus			1
Heterosternuta			1
Ilybius		-99	1
Neoporus			1
DIPTERA			
Ablabesmyia	13	28	14
Aedes			1
Anopheles	2	5	
Ceratopogoninae	3	6	1
Chironomidae	3	4	4
Chironomus		1	1
Corynoneura		18	17
Cricotopus bicinctus			1
Cricotopus/Orthocladius	6		
Cryptochironomus		3	
Diptera	1	1	
Dixella	2		4
Dolichopodidae			1
Forcipomyiinae	2		
Hemerodromia	33	2	2
Hexatoma			2
Kiefferulus			1

Aquid Invertebrate Database Bench Sheet Report**Logtown Br [15038], Station #1, Sample Date: 9/22/2015 10:20:00 AM****CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence**

ORDER: TAXA	CS	NF	RM
Labrundinia	1	2	
Micropsectra	1		1
Microtendipes	13	12	3
Nilothauma			1
Paracladopelma	1	1	
Paracricotopus	2		
Parametriocnemus	25		20
Paraphaenocladus		1	2
Paratanytarsus	33	3	48
Paratendipes	4	20	7
Phaenopsectra		9	7
Polypedilum flavum			1
Polypedilum illinoense grp	7	5	16
Polypedilum scalaenum grp		1	
Procladius			3
Pseudosmittia			1
Rheocricotopus	3		
Rheotanytarsus	4		
Saetheria	4		
Simulium	27		
Stempellinella		3	
Stenochironomus			1
Stictochironomus		1	
Tabanus	4	9	5
Tanytarsus	63	15	11
Thienemanniella	1	2	2
Thienemannimyia grp.	57		9
Tipula	63	4	9
Tribelos		18	9
Tvetenia bavarica grp	5		
Zavreliomyia	17	12	15
EPHEMEROPTERA			
Baetis	36		
Caenis anceps			1
Caenis latipennis		4	2

Aquid Invertebrate Database Bench Sheet Report**Logtown Br [15038], Station #1, Sample Date: 9/22/2015 10:20:00 AM****CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence**

ORDER: TAXA	CS	NF	RM
Centropilum	1	36	9
Dipheter	32		
Paraleptophlebia		1	15
Stenonema femoratum	13	42	5
Tricorythodes	2		
HEMIPTERA			
Gerris	1		
Mesovelgia			1
Microvelia	14		2
ISOPODA			
Caecidotea	1	2	9
Caecidotea (Blind & Unpigmented)		5	
LEPIDOPTERA			
Crambidae			-99
LUMBRICINA			
Lumbricina		3	
LUMBRICULIDA			
Lumbriculidae			1
MEGALOPTERA			
Sialis			1
ODONATA			
Argia			1
Calopteryx	4		6
Cordulegaster		1	
Dromogomphus			2
Enallagma			2
Hetaerina	5	1	7
TRICHOPTERA			
Ceratopsyche	3		
Cheumatopsyche	1		1
Chimarra	6		6
Hydroptila	4	1	
Oecetis	3		
Polycentropus	1		1

Aquid Invertebrate Database Bench Sheet Report**Logtown Br [15038], Station #1, Sample Date: 9/22/2015 10:20:00 AM****CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence**

ORDER: TAXA	CS	NF	RM
Ptilostomis	2		3
Triaenodes			6
TUBIFICIDA			
Branchiura sowerbyi	2		
Enchytraeidae	1		1
Tubificidae	1	6	12

Aquid Invertebrate Database Bench Sheet Report**Little St. Francis R [15037], Station #1, Sample Date: 9/22/2015 9:30:00 AM****CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence**

ORDER: TAXA	CS	NF	RM
"HYDRACARINA"			
Acarina	4	7	12
AMPHIPODA			
Hyaella azteca			20
BASOMMATOPHORA			
Ancylidae	1	1	
Helisoma			-99
Menetus		3	
COLEOPTERA			
Ancyronyx variegatus			2
Dubiraphia		10	3
Helichus basalis			1
Helichus lithophilus	2		2
Macronychus glabratus			1
Microcylloepus pusillus	3		5
Optioservus sandersoni	2		
Psephenus herricki	1		
Scirtidae			2
Stenelmis	34	3	6
Tropisternus			-99
DECAPODA			
Faxonius luteus	-99		
Faxonius virilis			-99
DIPTERA			
Ablabesmyia	4	28	8
Anopheles			2
Ceratopogoninae		8	3
Chironomidae		1	1
Cladotanytarsus	1	20	1
Corynoneura		1	1
Cricotopus bicinctus	3		5
Cricotopus/Orthocladius	9	2	13
Cryptochironomus		6	
Cryptotendipes		1	
Dicrotendipes		6	3

Aquid Invertebrate Database Bench Sheet Report**Little St. Francis R [15037], Station #1, Sample Date: 9/22/2015 9:30:00 AM****CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence**

ORDER: TAXA	CS	NF	RM
Dixella			10
Hemerodromia	7	1	
Hexatoma	4		
Labrundinia	1	5	27
Microtendipes	1	1	4
Nanocladius		1	1
Natarsia		1	
Nilotanytus	3		
Nilothauma		2	
Parachironomus			3
Parakiefferiella		1	
Paralauterborniella		10	
Parametriocnemus	1		
Paratanytarsus		7	20
Paratendipes		12	
Polypedilum flavum	10		1
Polypedilum halterale grp	1	4	
Polypedilum illinoense grp	1	3	9
Polypedilum scalaenum grp		3	
Procladius		2	
Pseudochironomus		2	1
Rheotanytarsus	19		2
Saetheria	15		
Simulium	7		
Stempellina		3	
Stempellinella	18	32	5
Tanytarsus	72	64	43
Thienemanniella	1		
Thienemannimyia grp.	1		
Tipula	1		
Tribelos		4	2
EPHEMEROPTERA			
Acentrella	1		
Acerpenna	7		
Apobaetis		1	

Aquid Invertebrate Database Bench Sheet Report**Little St. Francis R [15037], Station #1, Sample Date: 9/22/2015 9:30:00 AM****CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence**

ORDER: TAXA	CS	NF	RM
Baetis	1		
Caenis latipennis		46	14
Centroptilum		1	1
Choroterpes		-99	
Ephemera		-99	
Isonychia bicolor	11		
Leptophlebiidae		1	22
Leucrocuta	1		
Maccaffertium pulchellum	4		
Procloeon		5	
Stenacron	4	1	4
Stenonema femoratum		3	
Tricorythodes	251	1	7
HEMIPTERA			
Ranatra kirkaldyi			-99
Rhagovelia	2		
Rheumatobates			2
ISOPODA			
Caecidotea			3
LUMBRICINA			
Lumbricina	1	-99	
MEGALOPTERA			
Corydalus	3		
Sialis			-99
ODONATA			
Argia		3	8
Enallagma		1	16
Macromia		-99	-99
Progomphus obscurus		-99	
Somatochlora			-99
PLECOPTERA			
Acroneuria		-99	
TRICHOPTERA			
Cheumatopsyche	19		
Chimarra	12		

Aquid Invertebrate Database Bench Sheet Report**Little St. Francis R [15037], Station #1, Sample Date: 9/22/2015 9:30:00 AM****CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence**

ORDER: TAXA	CS	NF	RM
Oecetis		3	6
Polycentropus			12
Triaenodes			14
TUBIFICIDA			
Tubificidae	1	4	
VENEROIDA			
Corbicula	29	5	

Aquid Invertebrate Database Bench Sheet Report**Shays Cr [15034], Station #2, Sample Date: 9/21/2015 11:50:00 AM****CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence**

ORDER: TAXA	CS	NF	RM
"HYDRACARINA"			
Acarina	10		
BASOMMATOPHORA			
Ancylidae	1	1	
Lymnaeidae			1
Physella		1	
COLEOPTERA			
Dubiraphia	5	39	8
Helichus basalis			2
Macronychus glabratus	2		16
Scirtidae	2		
Stenelmis	41	2	14
DECAPODA			
Faxonius punctimanus			-99
DIPTERA			
Ablabesmyia	1	3	
Ceratopogoninae	1	3	1
Chironomidae	2		
Chironomus		19	1
Chrysops	4	1	
Clinotanypus		6	1
Corynoneura	2	3	
Cricotopus bicinctus	3		
Cricotopus/Orthocladius	1		
Cryptochironomus	1	3	
Cryptotendipes		1	
Diptera	1		
Goeldichironomus		1	
Hemerodromia	5		8
Micropsectra	1		1
Microtendipes		1	
Nilotanypus	3		1
Parametriocnemus	13	5	2
Paratanytarsus	1		

Aquid Invertebrate Database Bench Sheet Report**Shays Cr [15034], Station #2, Sample Date: 9/21/2015 11:50:00 AM****CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence**

ORDER: TAXA	CS	NF	RM
Paratendipes	1	7	
Pericoma		1	
Phaenopsectra		1	
Polypedilum fallax grp	1		
Polypedilum flavum	189	9	30
Polypedilum illinoense grp	10	5	5
Polypedilum scalaenum grp		2	
Pseudolimnophila			5
Psychoda	18		
Rheocricotopus	2		
Rheotanytarsus	32	7	3
Saetheria	19	2	
Simulium	18		1
Stempellinella	1		
Stictochironomus		7	
Tabanus	1		
Tanytarsus	17	10	1
Thienemanniella	13	2	2
Thienemannimyia grp.	46	4	14
Tipula	14		8
Zavrelimyia	1	2	
EPHEMEROPTERA			
Acentrella	1		
Baetis	23		
Caenis latipennis	21	12	9
Leptophlebiidae			1
HEMIPTERA			
Microvelia	1		1
Rhagovelia	2		1
ISOPODA			
Caecidotea	1		1
LUMBRICINA			
Lumbricina		2	
MEGALOPTERA			
Corydalus	-99		

Aquid Invertebrate Database Bench Sheet Report**Shays Cr [15034], Station #2, Sample Date: 9/21/2015 11:50:00 AM****CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence**

ORDER: TAXA	CS	NF	RM
Nigronia serricornis			-99
ODONATA			
Argia			1
Boyeria	-99		-99
Calopteryx	4		15
Gomphidae	1		1
Hagenius brevistylus	1		
Hetaerina	2		1
TRICHOPTERA			
Cheumatopsyche	32		12
Chimarra	10		10
Hydropsyche	3		12
Oecetis	3	1	17
Pycnopsyche			2
TRICLADIDA			
Planariidae	2		2
TUBIFICIDA			
Branchiura sowerbyi		4	
Enchytraeidae	2		
Limnodrilus hoffmeisteri			1
Tubificidae	26	151	38
VENEROIDA			
Pisidiidae	27	7	4

Aquid Invertebrate Database Bench Sheet Report**Shays Cr [15035], Station #1, Sample Date: 9/21/2015 2:25:00 PM****CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence**

ORDER: TAXA	CS	NF	RM
BASOMMATOPHORA			
Ancylidae	1	1	1
Physella	1		2
COLEOPTERA			
Ancyronyx variegatus		1	
Dubiraphia		8	32
Ectopria nervosa			1
Helichus basalis			1
Macronychus glabratus			7
Microcylloepus pusillus			2
Scirtidae			2
Stenelmis	36	2	28
DECAPODA			
Faxonius quadruncus	-99		
DIPTERA			
Ablabesmyia		10	
Anopheles			2
Brillia		1	
Chironomidae	8	5	
Chironomus		6	
Cladotanytarsus		1	
Corynoneura	6	1	1
Cricotopus/Orthocladius	3		
Cryptochironomus		3	1
Dicrotendipes	2	4	1
Hemerodromia	10		1
Hexatoma	5	-99	
Labrundinia		8	
Microtendipes	3	13	26
Nanocladius		1	4
Natarsia	1		1
Nilotanypus	20	1	4
Parametriocnemus	26		1
Paratanytarsus		6	4
Paratendipes		5	2

Aquid Invertebrate Database Bench Sheet Report**Shays Cr [15035], Station #1, Sample Date: 9/21/2015 2:25:00 PM****CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence**

ORDER: TAXA	CS	NF	RM
Phaenopsectra	1	8	1
Polypedilum fallax grp	7	3	
Polypedilum flavum	49		
Polypedilum illinoense grp	32	1	8
Polypedilum scalaenum grp	10	6	3
Rheocricotopus	4		
Rheotanytarsus	64	1	8
Simulium	22		
Stempellinella	68	46	13
Tabanus	3		
Tanytarsus	78	77	37
Thienemanniella	17	4	1
Thienemannimyia grp.	31	1	8
Tipula	3		
Tribelos		2	1
EPHEMEROPTERA			
Baetis	24		
Caenis anceps	1	7	3
Caenis latipennis	12	28	9
Centroptilum		1	
Eurylophella			1
Leucrocuta	1	2	
Maccaffertium pulchellum	2		
Paraleptophlebia		2	3
Stenacron	1	1	1
Tricorythodes	1		
HEMIPTERA			
Microvelia	1		6
Rhagovelia	2		1
ISOPODA			
Caecidotea	8	1	10
Caecidotea (Blind & Unpigmented)	1		
MEGALOPTERA			
Corydalus	-99		

Aquid Invertebrate Database Bench Sheet Report**Shays Cr [15035], Station #1, Sample Date: 9/21/2015 2:25:00 PM****CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence**

ORDER: TAXA	CS	NF	RM
Sialis		-99	
ODONATA			
Argia	1		3
Calopteryx	1		5
Enallagma			1
Hetaerina	4		
TRICHOPTERA			
Cheumatopsyche	77		3
Chimarra	26		
Hydropsyche	11		
Hydroptila		1	
Oecetis	5	2	21
Triaenodes		1	4
Wormaldia	1		
TRICLADIDA			
Planariidae	7		1
TUBIFICIDA			
Branchiura sowerbyi		1	1
Enchytraeidae	1		
Tubificidae	18	2	4
VENEROIDA			
Pisidiidae	9	4	10

Aquid Invertebrate Database Bench Sheet Report**Little St Francis R [16006], Station #2, Sample Date: 3/16/2016 11:00:00 AM****CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence**

ORDER: TAXA	CS	NF	RM
"HYDRACARINA"			
Acarina	5	3	5
AMPHIPODA			
Hyaella azteca			25
COLEOPTERA			
Berosus			1
Dineutus			-99
Dubiraphia		5	14
Ectopria nervosa	1		1
Helichus basalis			2
Macronychus glabratus			1
Psephenus herricki	2		
Stenelmis	31	3	1
DIPTERA			
Ablabesmyia			11
Ceratopogoninae		4	4
Chrysops	1		
Cladotanytarsus	10	26	4
Clinocera	13		
Corynoneura		1	1
Cricotopus bicinctus	1		1
Cricotopus sylvestris grp	1		
Cricotopus/Orthocladius	156	3	33
Cryptochironomus	3	4	
Cryptotendipes		4	
Dicrotendipes	2		1
Diptera		2	
Dolichopodidae	1		
Ephydriidae			1
Eukiefferiella	85		
Glyptotendipes			1
Hemerodromia	5	2	1
Hexatoma	3		
Hydrobaenus	10	1	1
Labrundinia			19

Aquid Invertebrate Database Bench Sheet Report**Little St Francis R [16006], Station #2, Sample Date: 3/16/2016 11:00:00 AM****CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence**

ORDER: TAXA	CS	NF	RM
Micropsectra	4		2
Microtendipes	26		1
Monodiamesa		1	
Nanocladius			1
Nilotanytus			1
Ormosia	2		
Paracladopelma		6	
Parakiefferiella	3		1
Parametriocnemus	6		
Paratanytarsus	1	1	14
Paratendipes		19	6
Phaenopsectra	3	8	8
Polypedilum aviceps	6		
Polypedilum flavum	6		
Polypedilum halterale grp		3	
Polypedilum illinoense grp	1		7
Polypedilum scalaenum grp	1	9	
Procladius		2	
Prosimulium	1		
Rheocricotopus			1
Rheotanytarsus	3		2
Simulium	16	1	
Stempellina		6	
Stempellinella	12	25	20
Stictochironomus		10	
Tanytarsus	98	39	80
Thienemanniella			2
Thienemannimyia grp.	16		12
Tipula	3		
Tvetenia bavarica grp	1	1	
EPHEMEROPTERA			
Acentrella	15		
Acerpenna	14		
Caenis anceps	4		
Caenis latipennis	25	23	43

Aquid Invertebrate Database Bench Sheet Report**Little St Francis R [16006], Station #2, Sample Date: 3/16/2016 11:00:00 AM****CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence**

ORDER: TAXA	CS	NF	RM
Centropilum			4
Ephemera	1		
Eurylophella bicolor			1
Fallceon	2		
Hexagenia		1	
Isonychia bicolor	4		
Leptophlebia			2
Leptophlebiidae	1		6
Maccaffertium pulchellum	3		
Stenonema femoratum	4	1	2
Tricorythodes	9		
ISOPODA			
Caecidotea			1
LUMBRICINA			
Lumbricina	9		
LUMBRICULIDA			
Lumbriculidae	1		
ODONATA			
Argia			2
Basiaeschna janata			1
Calopteryx			2
Enallagma			4
Gomphidae	1		2
Gomphus		1	
Libellula			-99
PLECOPTERA			
Amphinemura	13		
Capniidae	16		
Clioperla clio			-99
Hydroperla crosbyi	1		
Isoperla	31		
Leuctridae	1		
Perlidae	15		
Perlinella drymo			1
Prostoia	9		

Aquid Invertebrate Database Bench Sheet Report**Little St Francis R [16006], Station #2, Sample Date: 3/16/2016 11:00:00 AM****CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence**

ORDER: TAXA	CS	NF	RM
TRICHOPTERA			
Agapetus	2		
Cheumatopsyche	1		
Chimarra	4		
Hydroptila	1		
Nectopsyche	1		
Neureclipsis			2
Polycentropus		1	1
Ptilostomis			3
Pycnopsyche			-99
Rhyacophila	13		
Triaenodes			4
TUBIFICIDA			
Branchiura sowerbyi		1	
Enchytraeidae	1	1	
Limnodrilus claparedianus	1		
Limnodrilus hoffmeisteri	1	1	2
Tubificidae	5	18	1
VENEROIDA			
Pisidiidae	4	1	-99

Aquid Invertebrate Database Bench Sheet Report**Logtown Br [16005], Station #1, Sample Date: 3/16/2016 10:00:00 AM****CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence**

ORDER: TAXA	CS	NF	RM
"HYDRACARINA"			
Acarina	1	2	
AMPHIPODA			
Crangonyx	105	48	18
Stygobromus	1	2	
BASOMMATOPHORA			
Menetus		1	1
Physella			4
COLEOPTERA			
Ectopria nervosa	1		
Stenelmis		1	
DIPTERA			
Ablabesmyia		12	2
Ceratopogoninae	11		
Chaetocladius	1		
Chironomidae	7	2	2
Clinocera	4	8	1
Corynoneura	7	1	
Cricotopus/Orthocladius	243	66	136
Cryptochironomus		1	
Dicrotendipes	1		3
Diplocladius	1		
Diptera	1	9	2
Eukiefferiella	59	2	9
Hemerodromia	1		
Hydrobaenus	1	103	1
Micropsectra	2		3
Natarsia		2	
Ormosia	1		
Orthocladius (Euorthocladius)	1		
Paracladopelma		1	
Paracricotopus	2		
Parametriocnemus	6		1
Paraphaenocladius		1	

Aquid Invertebrate Database Bench Sheet Report**Logtown Br [16005], Station #1, Sample Date: 3/16/2016 10:00:00 AM****CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence**

ORDER: TAXA	CS	NF	RM
Paratanytarsus			1
Paratendipes		9	
Phaenopsectra		4	
Polypedilum aviceps	3		1
Procladius		2	
Prosimulium	63		64
Pseudosmittia		1	
Rheocricotopus	1	4	7
Simulium	18		6
Tabanus	2	4	
Tanytarsus	3	3	1
Thienemanniella	5	1	
Thienemannimyia grp.	7		4
Tipula	2		-99
Tvetenia bavarica grp	9		4
Zavrelimyia	5	13	2
EPHEMEROPTERA			
Ameletus	1		
Centropilum		2	4
Dipheter	3		
Leptophlebiidae	2		
Plauditus	4		1
Stenonema femoratum	1	1	
GORDIOIDEA			
Gordiidae	-99		
HEMIPTERA			
Microvelia			2
ISOPODA			
Caecidotea	22	6	14
Caecidotea (Blind & Unpigmented)		10	
ODONATA			
Calopteryx		1	2
PLECOPTERA			
Amphinemura	33		10

Aquid Invertebrate Database Bench Sheet Report**Logtown Br [16005], Station #1, Sample Date: 3/16/2016 10:00:00 AM****CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence**

ORDER: TAXA	CS	NF	RM
Hydroperla crosbyi	1		
Isoperla	22		2
Leuctridae	3		
Perlesta	5		
Zealeuctra	1		
TRICHOPTERA			
Cheumatopsyche	1		
Hydroptila	1		
Isonychia	-99		1
Lepidostoma	2		
Nectopsyche			1
Platycentropus		1	1
Polycentropus	2		
Rhyacophila	3		
Triaenodes			5
TRICLADIDA			
Planariidae	2		
TUBIFICIDA			
Enchytraeidae	3	2	
Tubificidae	4	5	
VENEROIDA			
Corbicula	1		
Pisidiidae		2	

Aquid Invertebrate Database Bench Sheet Report**Little St Francis R [16004], Station #1, Sample Date: 3/16/2016 8:45:00 AM****CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence**

ORDER: TAXA	CS	NF	RM
"HYDRACARINA"			
Acarina	4	5	4
AMPHIPODA			
Hyaella azteca			4
BASOMMATOPHORA			
Ferrissia	2		
COLEOPTERA			
Ancyronyx variegatus		1	
Dubiraphia	4	3	18
Helichus basalis	1		1
Helichus lithophilus	1		
Macronychus glabratus			3
Microcylloepus pusillus	2		1
Stenelmis	64	1	9
DIPTERA			
Ablabesmyia		6	4
Chironomidae		1	1
Cladotanytarsus	17	22	
Clinocera	8		
Cricotopus/Orthocladius	117	7	14
Cryptochironomus		1	
Cryptotendipes		3	
Dicrotendipes		6	
Diptera		1	1
Eukiefferiella	39		3
Hemerodromia	4	3	
Hydrobaenus	2	4	2
Labrundinia		1	14
Limnophila	1		
Micropsectra	2	1	
Microtendipes	9		3
Nanocladius			2
Paralauterborniella		4	1
Parametriocnemus	4		
Paratanytarsus		2	12

Aquid Invertebrate Database Bench Sheet Report**Little St Francis R [16004], Station #1, Sample Date: 3/16/2016 8:45:00 AM****CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence**

ORDER: TAXA	CS	NF	RM
Paratendipes		43	1
Phaenopsectra		18	
Polypedilum aviceps	8		
Polypedilum flavum	5		
Polypedilum halterale grp		9	
Polypedilum illinoense grp	1	3	
Polypedilum scalaenum grp	2	11	
Procladius			1
Prosimulium	2		
Rheocricotopus	2		4
Rheotanytarsus	3		3
Saetheria	2		
Simulium	18		
Stempellinella	13	20	13
Stictochironomus	1	1	
Stratiomys	1		
Tabanus	1	1	
Tanytarsus	106	55	70
Thienemanniella		1	
Thienemannimyia grp.	5	1	5
Tipula	3		-99
EPHEMEROPTERA			
Acerpenna	5		
Caenis anceps			9
Caenis latipennis	24	18	76
Centroptilum			4
Ephemera simulans	-99		
Eurylophella enoensis	1		1
Isonychia bicolor			-99
Leptophlebia		-99	-99
Leptophlebiidae			3
Maccaffertium pulchellum	8		1
Maccaffertium terminatum	1		
Plauditus	4		
Stenacron		1	2

Aquid Invertebrate Database Bench Sheet Report**Little St Francis R [16004], Station #1, Sample Date: 3/16/2016 8:45:00 AM****CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence**

ORDER: TAXA	CS	NF	RM
Stenonema femoratum	7	3	-99
Tricorythodes	11	1	3
ISOPODA			
Caecidotea		1	-99
LUMBRICINA			
Lumbricina	6		
MEGALOPTERA			
Corydalus	-99		
ODONATA			
Arigomphus			-99
Basiaeschna janata			-99
Calopteryx			-99
Didymops		-99	
Enallagma			6
Macromia			-99
PLECOPTERA			
Allocapnia	2		
Amphinemura	6		1
Hydroperla crosbyi	1		
Isoperla	20		
Perlidae	24		5
Prostoia	2		
TRICHOPTERA			
Cheumatopsyche	3		2
Chimarra	1		
Hydroptila	6		
Nectopsyche	1		
Oecetis			5
Polycentropus			-99
Ptilostomis			-99
Pycnopsyche			-99
Rhyacophila	3		
Trienodes			6
TUBIFICIDA			
Enchytraeidae		1	

Aquid Invertebrate Database Bench Sheet Report**Little St Francis R [16004], Station #1, Sample Date: 3/16/2016 8:45:00 AM****CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence**

ORDER: TAXA	CS	NF	RM
Limnodrilus hoffmeisteri	1	1	
Tubificidae	2	10	1
VENEROIDA			
Corbicula	15	3	

Aquid Invertebrate Database Bench Sheet Report**Shays Cr [16000], Station #2, Sample Date: 3/15/2016 11:50:00 PM****CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence**

ORDER: TAXA	CS	NF	RM
"HYDRACARINA"			
Acarina	3	1	1
AMPHIPODA			
Crangonyx	5	1	1
BASOMMATOPHORA			
Physella	1	1	3
COLEOPTERA			
Dubiraphia	1	2	6
Ectopria nervosa			1
Macronychus glabratus	2	1	8
Stenelmis	49		5
Tropisternus			1
DIPTERA			
Ablabesmyia		5	2
Ceratopogoninae	5	12	1
Chironomidae		1	
Chironomus		5	
Clinocera	3		1
Cricotopus/Orthocladius	140	29	95
Cryptochironomus	23	12	3
Cryptotendipes		1	
Dixella			1
Eukiefferiella	95	3	39
Eukiefferiella brehmi grp	1		
Hemerodromia	29	6	4
Hydrobaenus		8	
Labrundinia		1	
Limnophila	2		
Micropsectra	2	1	1
Microtendipes	2	3	1
Parametriocnemus	5		2
Paraphaenocladius			1
Paratanytarsus		1	6
Paratendipes		15	

Aquid Invertebrate Database Bench Sheet Report**Shays Cr [16000], Station #2, Sample Date: 3/15/2016 11:50:00 PM****CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence**

ORDER: TAXA	CS	NF	RM
Phaenopsectra			1
Polypedilum aviceps	14		7
Polypedilum flavum	16	3	4
Polypedilum scalaenum grp	3	12	
Procladius		1	
Pseudolimnophila	3	1	1
Rheocricotopus	5		
Rheotanytarsus	6	2	5
Simulium	14		4
Stempellinella	3	6	2
Stictochironomus		3	
Tabanus	2	1	
Tanytarsus	60	84	8
Thienemannimyia grp.	32	2	17
Tipula	3	1	-99
Tvetenia bavarica grp			4
Tvetenia vitracies			1
EPHEMEROPTERA			
Caenis latipennis	9	7	4
Centropilum		1	
Leptophlebia			2
GORDIOIDEA			
Chordodidae	1		
HEMIPTERA			
Hebrus			1
Microvelia			1
ISOPODA			
Caecidotea			1
LEPIDOPTERA			
Crambidae			-99
MEGALOPTERA			
Nigronia			-99
ODONATA			
Argia	1		2
Boyeria	1		1

Aquid Invertebrate Database Bench Sheet Report**Shays Cr [16000], Station #2, Sample Date: 3/15/2016 11:50:00 PM****CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence**

ORDER: TAXA	CS	NF	RM
Calopteryx		-99	23
Dromogomphus		-99	1
Enallagma			1
Hagenius brevistylus		1	
PLECOPTERA			
Amphinemura	12		
Perlesta	14		
TRICHOPTERA			
Cheumatopsyche	4		
Chimarra	7		
Helicopsyche	6		
Hydropsyche	5	1	1
Hydroptila	6		
Ironoquia			1
Oecetis	2		6
Polycentropus	3	-99	
Ptilostomis		-99	
Pycnopsyche			1
Rhyacophila	1		
TRICLADIDA			
Planariidae	7		2
TUBIFICIDA			
Branchiura sowerbyi	1		
Limnodrilus hoffmeisteri	5	4	
Limnodrilus udekemianus	2		
Tubificidae	44	43	6
VENEROIDA			
Corbicula	21	6	32
Pisidiidae	11	5	6

Aquid Invertebrate Database Bench Sheet Report**Shays Cr [16001], Station #1, Sample Date: 3/15/2016 1:20:00 PM****CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence**

ORDER: TAXA	CS	NF	RM
"HYDRACARINA"			
Acarina	1	2	1
AMPHIPODA			
Crangonyx		-99	1
BASOMMATOPHORA			
Ancylidae	5		1
Physella	1		3
COLEOPTERA			
Agabus			-99
Ancyronyx variegatus	2		1
Dubiraphia	3		13
Macronychus glabratus	1		4
Microcylloepus pusillus			1
Stenelmis	26	2	3
DIPTERA			
Ablabesmyia			1
Ceratopogoninae	1	3	
Chironomidae	1	3	
Cladotanytarsus		10	
Corynoneura	2		10
Cricotopus/Orthocladius	38	32	43
Cryptochironomus	5	12	3
Dicrotendipes			1
Diptera		1	
Eukiefferiella	117	11	24
Forcipomyiinae		1	
Hemerodromia	18		7
Hexatoma	1	1	1
Hydrobaenus		6	3
Labrundinia			1
Micropsectra	3	1	9
Microtendipes	1	2	3
Natarsia		1	
Nilotanypus	1	1	
Parametriocnemus	2		

Aquid Invertebrate Database Bench Sheet Report**Shays Cr [16001], Station #1, Sample Date: 3/15/2016 1:20:00 PM****CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence**

ORDER: TAXA	CS	NF	RM
Paratanytarsus	3	1	8
Paratendipes		30	1
Phaenopsectra	1	7	
Polypedilum aviceps	61	1	14
Polypedilum fallax grp			1
Polypedilum flavum	3		2
Polypedilum illinoense grp	3		13
Polypedilum scalaenum grp	31	44	1
Pseudolimnophila	1		
Rheocricotopus	2		4
Rheotanytarsus	22	1	39
Simulium	13		1
Stempellinella	14	44	11
Stenochironomus			1
Stictochironomus	2	1	
Tabanus	-99	1	
Tanytarsus	63	78	25
Thienemanniella		1	6
Thienemannimyia grp.	27	8	23
Tipula	2	1	
Tvetenia	4		
Tvetenia bavarica grp	1		2
EPHEMEROPTERA			
Acentrella	1		
Caenis latipennis	6	21	21
Dipheter	1		
Eurylophella enoensis			1
Maccaffertium pulchellum	2	1	1
Stenacron	1	-99	
HEMIPTERA			
Microvelia			1
ISOPODA			
Caecidotea	7		6
Caecidotea (Blind & Unpigmented)		-99	

Aquid Invertebrate Database Bench Sheet Report**Shays Cr [16001], Station #1, Sample Date: 3/15/2016 1:20:00 PM****CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence**

ORDER: TAXA	CS	NF	RM
LUMBRICINA			
Lumbricina	1	-99	
MEGALOPTERA			
Nigronia serricornis			-99
ODONATA			
Argia			1
Boyeria			-99
Calopteryx			7
PLECOPTERA			
Amphinemura	1		
Leuctridae	2		
Perlidae	1		1
TRICHOPTERA			
Cheumatopsyche	3		2
Chimarra	4		
Helicopsyche	2	1	
Hydropsyche	4		
Hydroptila	17	2	
Oecetis		1	15
Pycnopsyche			1
Rhyacophila	5	1	
Triaenodes			3
TRICLADIDA			
Planariidae	22	2	
TUBIFICIDA			
Enchytraeidae	4	2	2
Limnodrilus hoffmeisteri		1	
Tubificidae	1	9	
VENEROIDA			
Pisidiidae	3	6	2